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D. M. BEACH, *Editor*

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The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to described conditions.

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ESSENTIAL FEATURES OF TRIAXIAL SHEAR TESTS [1]

BY THE DIVISION OF TESTS, U. S. PUBLIC ROADS ADMINISTRATION

Reported by C. A. HOGENTOGLER, Senior Highway Engineer and E. S. BARBER, Junior Highway Engineer

IN THE DESIGN of retaining walls, three types of earth pressure may be considered.

Without movement of the earth, pressures against the walls, figure 1—A and 1—B, become the "earth pressures at rest" which depend upon the coefficient K, expressed by the relation

$$K=\frac{l}{v}$$

In which

l=lateral pressure,
v=vertical pressure.

However, soil must deform to fail. The pressures it produces at maximum deformation without failure are termed active or passive, depending on the directions of the applied forces responsible.

Wedges (*1, 2*)[2] assumed in the design of retaining walls (fig. 1) have lower boundaries, D—D, on which the soil slips when it shears. Weight of the earth in figure 1—A produces the active earth pressure which forces walls outward and causes D—D to incline at an angle a with the horizontal and b with the vertical. Forcing walls backward as in figure 1—B, produces the passive earth pressure which causes D—D to incline at an angle b with the horizontal and a with the vertical.

The diagram of supporting value of soil under a strip load, considered in a formula published in PUBLIC ROADS (*3*), is shown in figure 1—C.

Beneath each half of the load, which acts like an embankment breaking in the middle, is a triangular diagram of active earth pressure similar to the one shown in figure 1—A. It is assumed that wedges of earth beneath the surface adjacent to the loaded area and subjected to passive earth pressure function like retaining walls to prevent failure of the wedges subjected to the active earth pressure. Therefore, diagrams of passive earth pressure similar to the one shown in figure 1—B are used to complete the diagram of the supporting value of the soil (fig. 1—C). The angle a and its complement b are utilized also in theories suggested for the determination of stresses in embankments (*4*), soil foundations for rigid loads (*5*), and flexible type pavements (*6, 7*).

The coefficient of earth pressure at rest, K, (*8*) depends upon the soil's elasticity rather than its resistance to shear. Active and passive earth pressures in contrast depend upon the soil's cohesion c, and its angle of internal friction ϕ.

EARTH PRESSURES STUDIED EXTENSIVELY

Tests to determine relations of the laterial to applied vertical pressures on soil and their use to furnish design data have become accepted practice.

In 1900 J. A. Jamieson (*9*) a Canadian engineer, utilized manometers as shown in figure 2 to measure both lateral and vertical pressures of grain in model bins. About the same time, E. P. Goodrich, investigating pressures against retaining walls, utilized the apparatus shown in figure 3, and his findings published in 1904 (*10*) are substantiated by later work in this country (*11, 12*) and quite recently by extensive investigations in Germany (*13*).

On January 18, 1933, F. N. Hveem filed an application for letters patent on a stabilometer, figures 4 and 5, to test various sorts of reasonably stiff plastic ma-

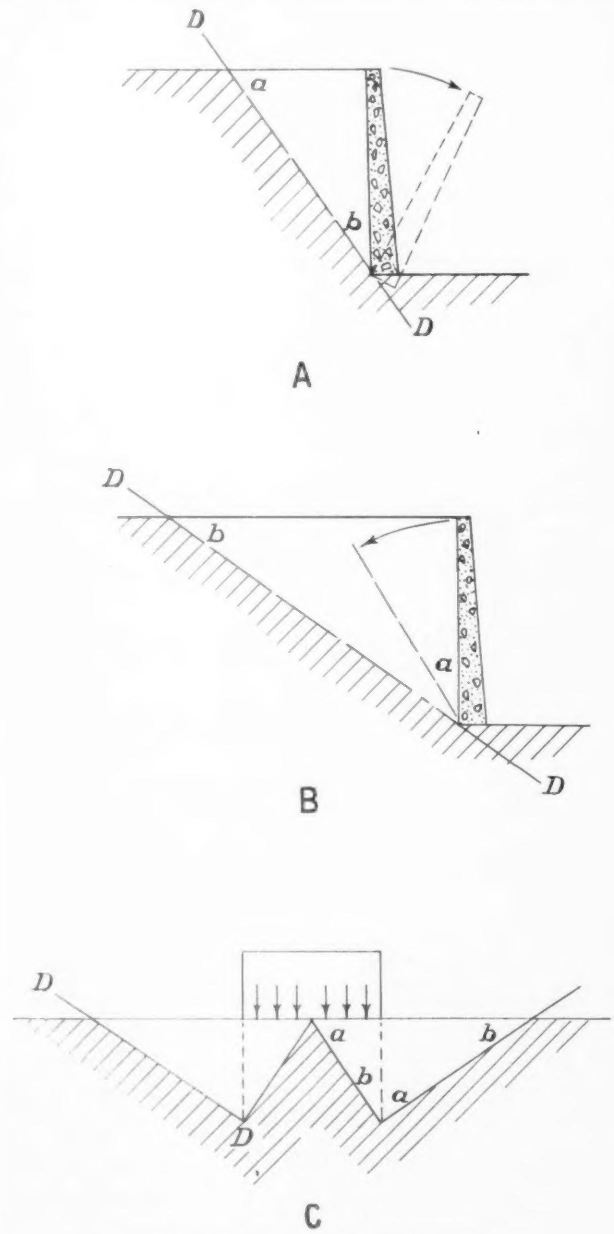

FIGURE 1.—SURFACES OF SLIP ILLUSTRATED.

[1] Paper presented at the annual meeting of the American Society for Testing Materials, Atlantic City, N. J., June 28, 1939.
[2] Italic figures in parenthesis refer to bibliography, p. 153.

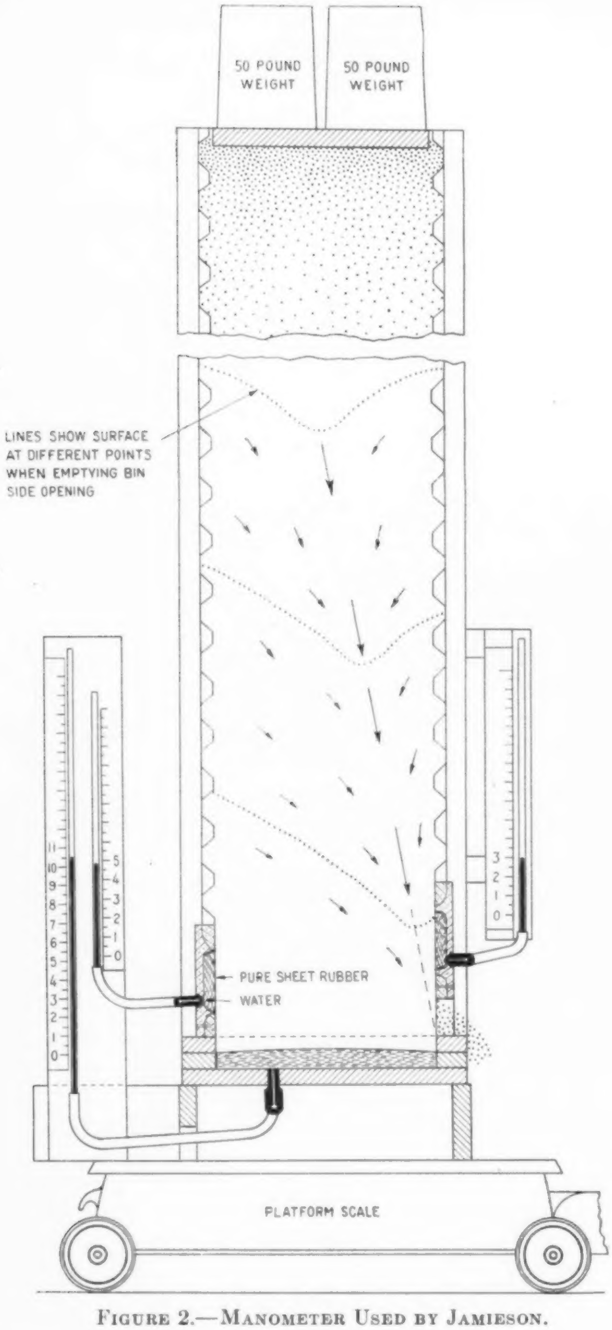

FIGURE 2.—MANOMETER USED BY JAMIESON.

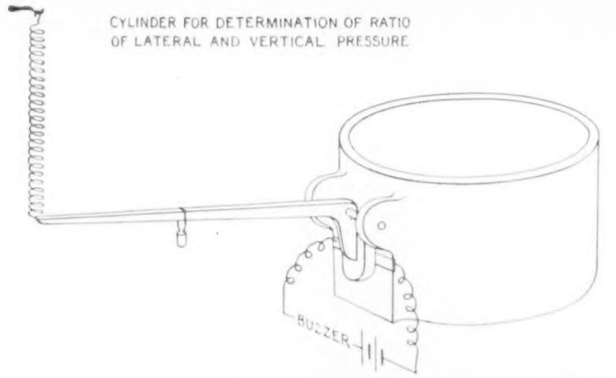

FIGURE 3.—APPARATUS DEVISED BY GOODRICH FOR DETERMINING RATIO OF LATERAL TO VERTICAL PRESSURES.

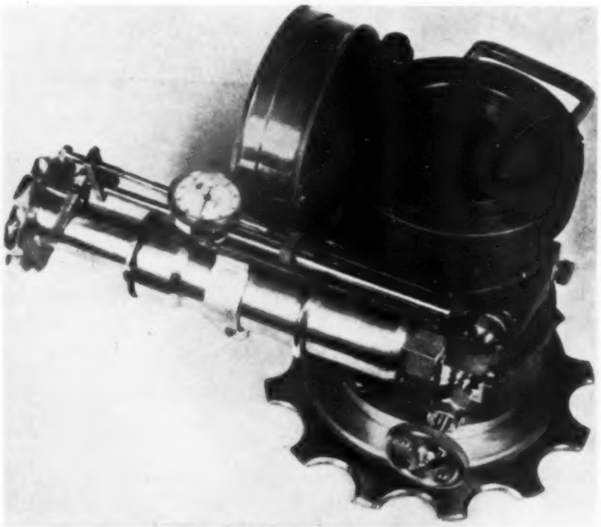

FIGURE 4.—STABILOMETER DEVELOPED BY HVEEM.

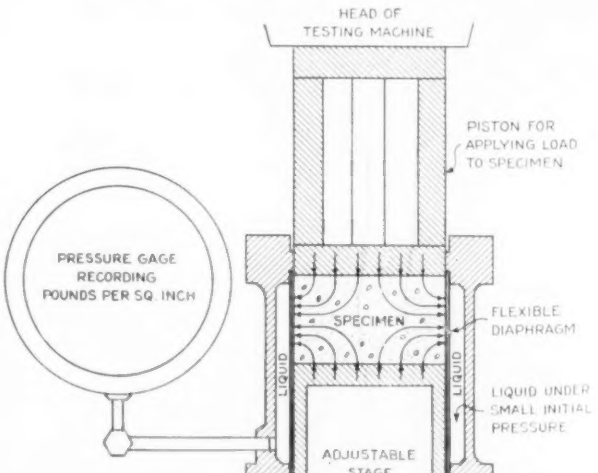

FIGURE 5.—DIAGRAM OF STABILOMETER DEVELOPED BY HVEEM.

terials, such as clay, soil (to determine bearing values), etc. The apparatus had essential features as follows:

1. Flexible cylinder arranged concentrically within a cylindrical shell, a pressure chamber being formed between the two.
2. Specimens in the flexible cylinder loaded axially and means to measure accompanying changes in the chamber pressures.
3. Means to measure deformations of the specimens in the direction of load and perpendicular to it. The patent [3] was granted April 23, 1935 (*14*).

In Hveem's apparatus the flexible rubber cylinder is attached at both ends to the pressure chamber, which in turn is of metal and filled with a liquid.

[3] U. S. Patent Office No. 1998722.

In 1934, Leo Jürgenson (*15*) described apparatus in which the rubber was fixed at but one end to the chamber, and which utilized compressed air to maintain

FIGURE 6.—RUBBER SLEEVE AND CLAMPS USED TO ENCASE SAMPLES FOR STABILOMETER TESTS.

constant pressure in the chamber. In the same year Keverling Buisman of Delft, Netherlands, (*16*) suggested the use of transparent material for the outer shell.

Since then modifications of these basic conceptions have been reported by: Delft Laboratories, 1936 (*17*); W. S. Housel, 1936 (*18*); Seibert and Palmer, 1938 (*19*); John D. Watson, 1938 (*20*); Corps of Engineers, United States Army, 1939 (*21*); and the Public Roads Administration, Levi Muir, the Shell Oil Co., and the Bureau of Reclamation in 1939 (*22*).

Purposes of the tests, types of soil investigated, and laboratory facilities necessitated procedures and equipment which varied widely in some respects and yet had enough in common to suggest use of simplified apparatus with interchangeable parts to satisfy all the requirements. Methods employed include a "closed" system which prevents volume change of samples, and an "open" system which permits their swell or con-

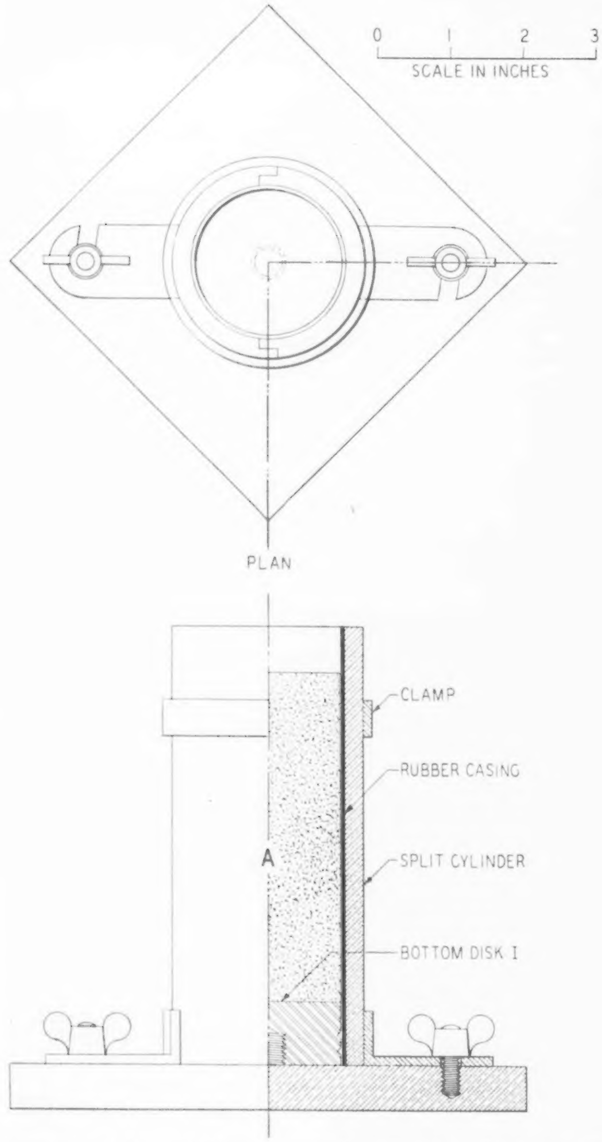

FIGURE 7.—MOLD USED FOR COMPACTING SAMPLES FOR STABILOMETER TESTS.

solidation during test. An impervious encasement which prevents entrance or escape of air and water encloses samples in the closed system, and placing them between porous stones provides for the entrance or egress of air and water in the open system.

PRESSURE CHAMBER SUGGESTED FOR USE IN PREPARING SAMPLES

For stabilometer tests, cylindrical samples are encased in rubber sleeves clamped about bakelite disks (fig. 6) which, with or without porous stones, are placed at the ends of the samples. Samples of stabilized soil and embankment materials may be compacted in the apparatus shown in figure 7.

For tests using the closed system, compacted samples are placed in the rubber jackets with impervious disks at the bottom ends, and, after removal from the split cylinder mold, impervious disks are also placed at their upper ends. The clamps are adjusted and threaded studs screwed into the bottom disks as shown in figure 8—B. This assembly can also be used for testing undisturbed samples at their natural moisture contents.

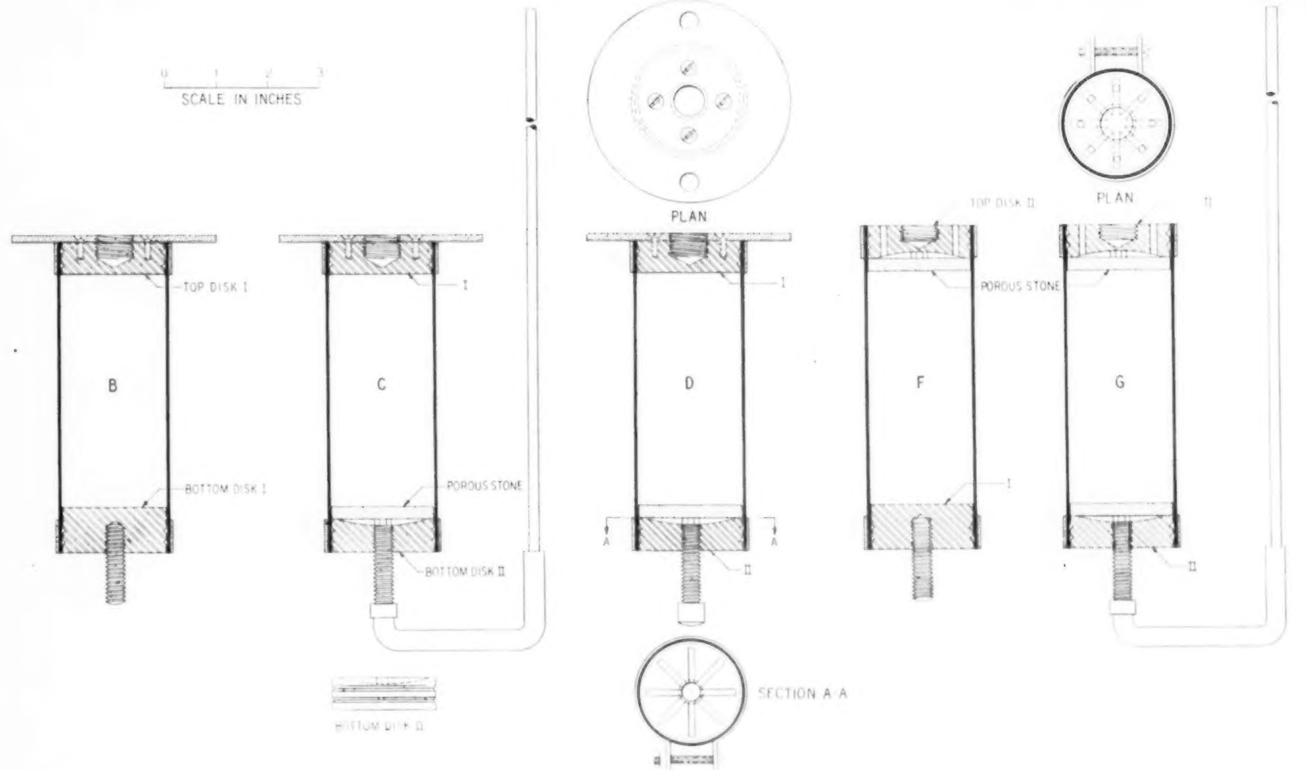

FIGURE 8.—ASSEMBLIES SHOWING POROUS STONES AND DISKS PLACED AT ENDS OF SAMPLES.

Studs afford means to fasten sample assemblies in the stabilometers, and threaded recesses in the top disks afford means for attachment to plungers of the stabilometers.

Determinations of the critical density of sands may be desired also. The critical density has been defined by Arthur Casagrande (*23*) as that density at which a soil can undergo deformation or actual flow without volume change, (see also (*24*)). For this purpose assembly C is suggested.

Assembly G (fig. 8) is suggested for use in determining permeabilities and capillarities of samples by application of water through the porous stone and tube in the bottom disk, which furnishes a connection with the burette. At times, tests on samples at the pore pressures of the pressure chamber may be required. Assembly F is suggested for this purpose.

The apparatus shown in figure 9 is usable in the pretesting of samples for consolidation and swell (see also (*15*, *25*)). Rise of water in the burette, assembly C, discloses the speed and amount of consolidation of samples at the applied air pressures; and drop of water in the burette indicates their swell. Metal guides attached to the top disks are to prevent tilting of samples during such tests.

At the conclusion of the preliminary tests, all spaces in porous stones, disks and tubes at the bottoms of assemblies C and G are filled with water. Disconnecting the burettes and capping the tubes and, for assembly G, replacing the perforated top disk with an impervious one, completes the change to assembly D (fig. 8).

Figure 10 is a diagram of a pressure chamber and sample assembly which is usable in the closed system of test. A nut on the tube fastens the assembly D to the chamber. A similar nut on the threaded stud, assembly B, serves a similar purpose.

Attaching one end only of sample assemblies to the pressure chamber distinguishes the stabilometer, figure 10, as the free rubber type used by Jürgenson, Delft Laboratories, Harvard University, Corps of Engineers, United States Army, and the Bureau of Reclamation.

Harvard University and the Corps of Engineers suggest glycerine as a liquid satisfactory for use in the cylinder. To prevent leakage, Harvard University utilized the stuffing box (fig. 11) and the Corps of Engineers, the bronze bushing (fig. 10).

Relative to experience at Harvard University, John D. Watson (*20*) states:

> It is absolutely essential that friction between this piston and the head be reduced to a negligible amount. At the same time it must be possible to maintain the hydrostatic pressure in the compression chamber constant while a test is in progress. A highly viscous fluid in the compression chamber would be far better than air because air under pressure is very difficult to confine without leakage. Glycerine was chosen because in addition to a high viscosity it is soluble in water and easy to wash off and clean up, and it does not attack rubber. The piston rod is jacketed with graphite steam packing but the packing gland is screwed down so little that the piston rod will fall slowly under its own weight.

Relative to the use of the bronze bushing, a report by the Corps of Engineers (*21*) states:

> The hemp packing box has been eliminated and a bronze bushing substituted in its place. Experience has shown that friction is eliminated thereby and that leakage of glycerine even at high hydrostatic pressures is negligible.

Relative to the closed system, a report (*22*) on the Bureau of Reclamation's apparatus states:

> The specimens are encased in thin-wall rubber tubes which clamp to metal end plates, thus keeping the water which completely fills the pressure cylinder from wetting them.

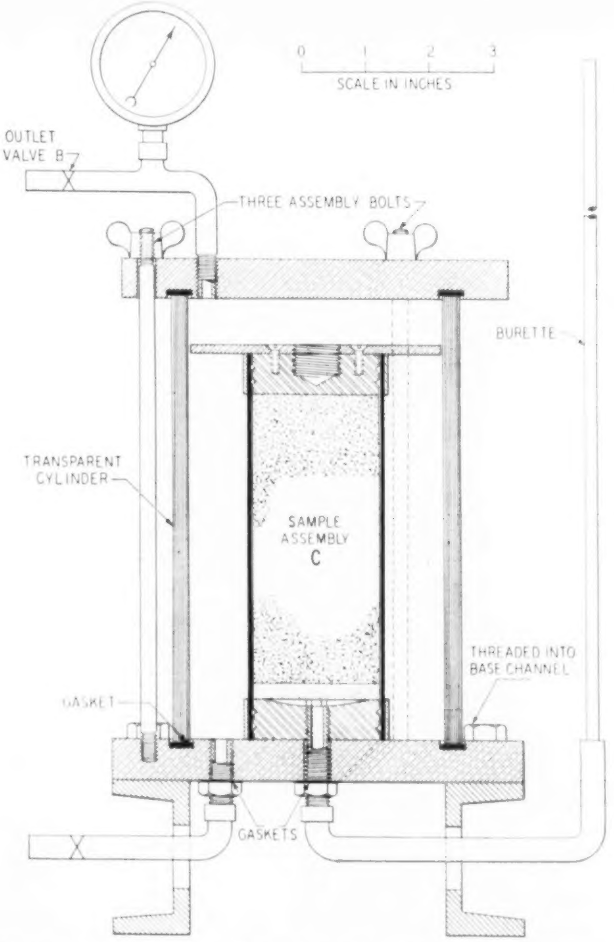

FIGURE 9.—PRESSURE CHAMBER FOR USE IN CONSOLIDATING SAMPLES.

COEFFICIENT *K* DETERMINED USING THE FIXED RUBBER TYPE OF STABILOMETER

It is convenient to arrange the stabilometer in loading devices so that upward movement of the plunger is prevented while pressures within the chamber are increased to those selected for use in the tests. At particular lateral pressures thus provided, samples are compressed to failure by vertical pressures applied through the plunger.

Figure 12 illustrates the failure of a cylindrical sample. As the cylinder shortens it bulges first (fig. 12–B) and then fails along the surfaces of slip (fig. 12–C and 12–D) which incline to the horizontal at the angle a shown in the diagrams, figure 1.

Tests on samples comprised of differently colored modeling clays disclosed the deformations, figure 13, undergone by the layers which had uniform thicknesses prior to test.

Reduction of the vertical pressure, accompanied by increase of lateral pressures, facilitates removal of samples from the chamber and container by reducing their diameters.

Analyses of test data by means of Mohr's circles of stress has been described in PUBLIC ROADS (*26*). Common tangents which disclose the values of c and ϕ are drawn to arcs constructed from a knowledge of the vertical pressures, v, and the lateral pressures, l, on the sample at failure.

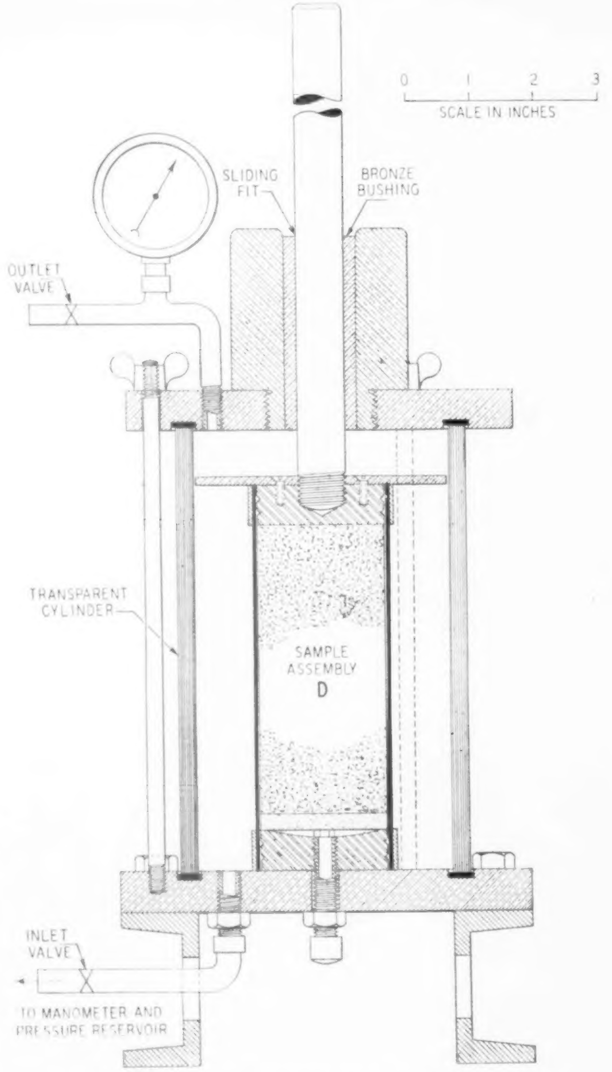

FIGURE 10.—STABILOMETER OF THE PLUNGER TYPE.

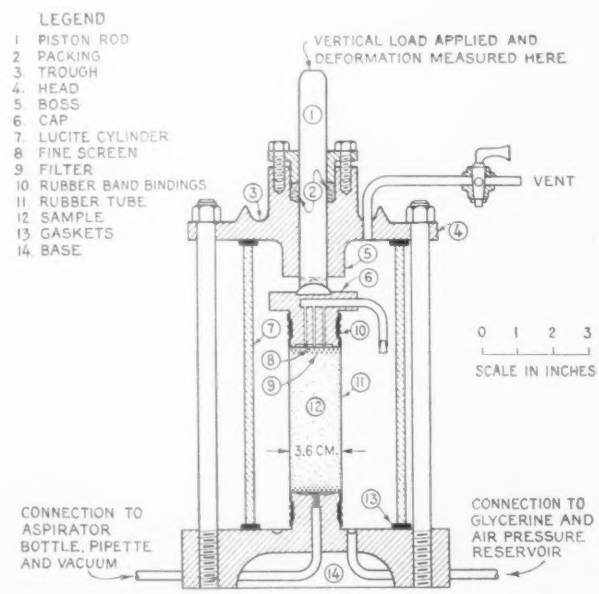

FIGURE 11.—THE TRIAXIAL COMPRESSION CHAMBER.

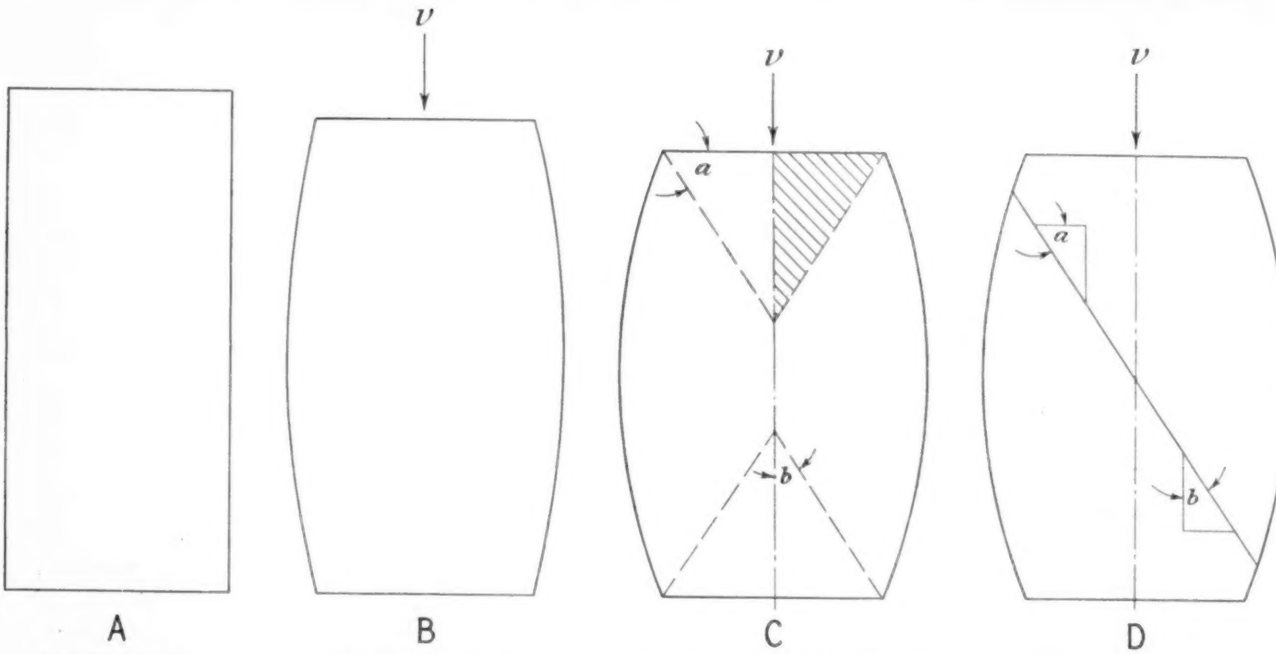

Figure 12.—Deformation of the Sample During Testing.

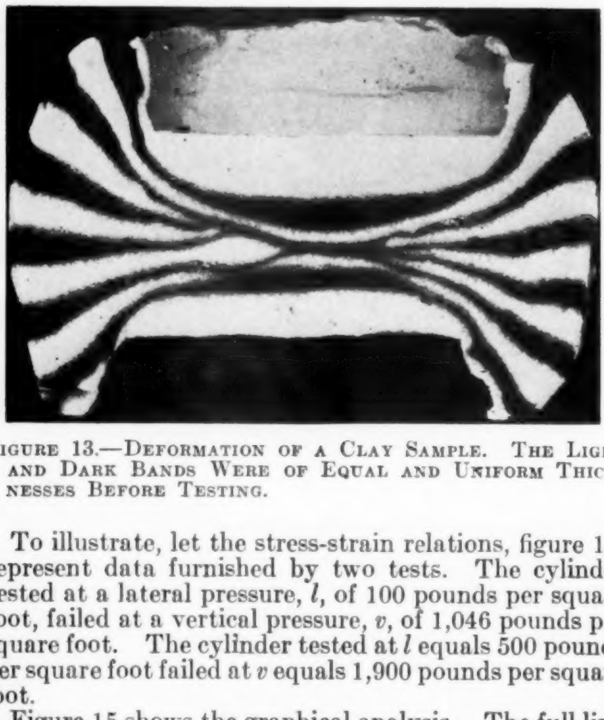

Figure 13.—Deformation of a Clay Sample. The Light and Dark Bands Were of Equal and Uniform Thicknesses Before Testing.

To illustrate, let the stress-strain relations, figure 14, represent data furnished by two tests. The cylinder tested at a lateral pressure, l, of 100 pounds per square foot, failed at a vertical pressure, v, of 1,046 pounds per square foot. The cylinder tested at l equals 500 pounds per square foot failed at v equals 1,900 pounds per square foot.

Figure 15 shows the graphical analysis. The full line at the top shows the relation between shear stress and normal pressure at failure of the cylinders. The straight broken lines show similar relations for strains less than the ultimate.

The arcs have centers on the abscissa at a distance of $\frac{v+l}{2}$ from the origin, and radii to the same scale of $\frac{v-l}{2}$. This places the center of the smaller full line circular arc at the point corresponding to $\frac{1{,}046+100}{2}$ pounds per square foot, and makes its radius equivalent to $\frac{1{,}046-100}{2}$ pounds per square foot.

As the next step, the relations of c and ϕ to deformations of the samples may be shown as previously described (*8*, *27*).

Use of sample assembly C with the special manometer, figure 16, permits the determination of pore pressures within samples during test. The special manometer has been discussed elsewhere (*25*, *28*).

In the determination of coefficients of earth pressure at rest, lateral deformation of samples is confined to a minimum. For this purpose, the stabilometer, figure 17, is suggested. By the use of sample assembly G and at the discretion of the operator, water may be applied directly to the sample's top and by the connection through the lower disk, to its bottom.

The rubber sleeve of the sample assembly attached at both ends to the pressure chamber, distinguishes the stabilometer, figure 17, as the fixed rubber type which has been used by Hveem, Buisman, Housel, Seibert and Palmer, Muir, the Shell Oil Company and the Delft Laboratories (*22*). Figure 18 shows stabilometers of the free and fixed rubber types.

In making the test for K, the chamber is completely filled with water and both outlet and inlet valves are closed to prevent escape of the water during test. The vertical pressure is then applied through the plunger, and the gradually increasing lateral pressures are read from the gage.

Relations of K to moisture content of a soil are obtained from samples compacted at or consolidated to different moisture contents and tested at pressures within the range for which information is desired.

The stabilometer, figure 17, with confinement of liquid in the pressure chamber, typifies also the cell apparatus, figure 19, used at the present time to test the soft undersoils for which Holland is noted. Thirty-eight of the devices were in use at the Delft Laboratories

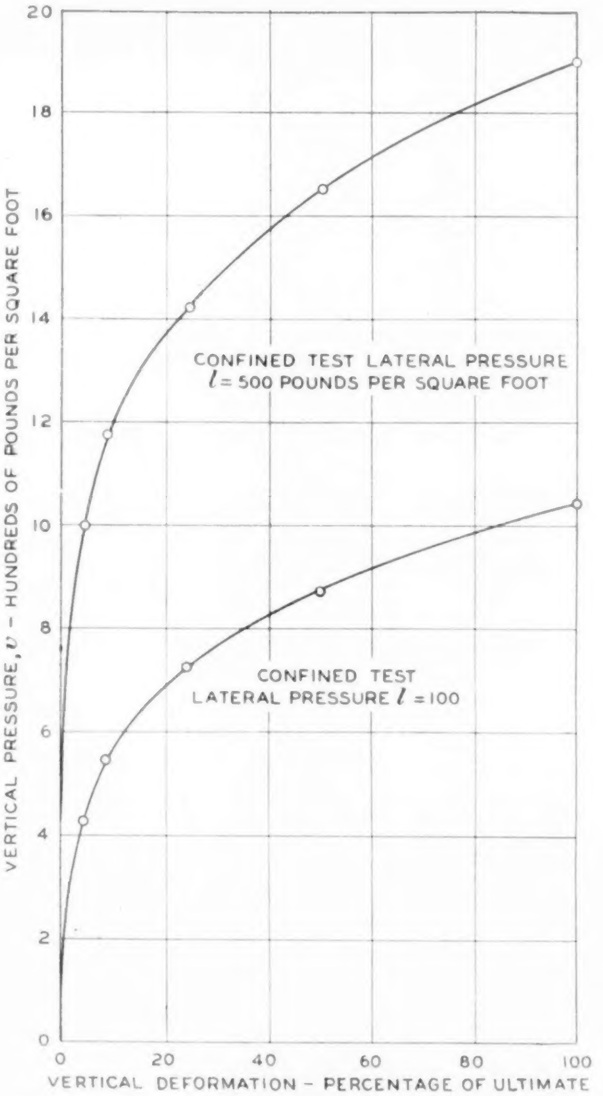

FIGURE 14.—STRESS-STRAIN RELATIONS FOR TWO SAMPLES.

in the summer of 1938, and 25 more had been prepared for shipment to the University of Ghent, Belgium.

The testing procedure, described elsewhere (*22*) provides for escape of the liquid, in small amounts at a time, from the chamber. This in turn causes increasing shear resistance to be developed as the soil deforms. Its unique feature is the testing of but one sample to obtain values of c and ϕ of an undisturbed soil at its natural moisture content. For shear tests of the same soil at lower moisture contents, samples are first consolidated in the stabilometers.

VARIOUS FEATURES OF APPARATUS DISCUSSED

The long period of time required for this makes it advisable to preconsolidate the samples in the separate chamber, figure 9.

The impervious top disk of the sample, assembly C, would then be replaced by the porous stone and perforated disk, assembly G, and the rubber sleeve slipped over and clamped about the metal extension as shown in figure 17.

The selection of the type of stabilometer depends primarily upon the size of the samples to be tested,

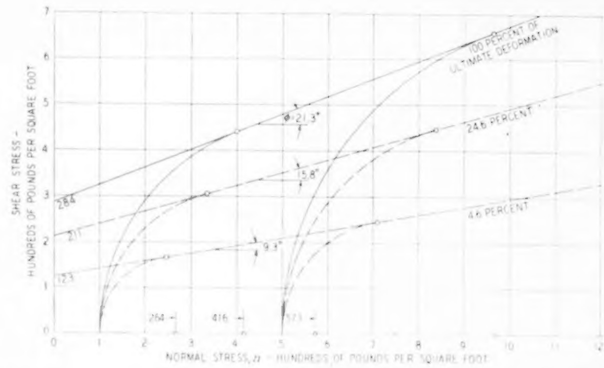

FIGURE 15.—GRAPHICAL ANALYSIS OF STRESSES IN CYLINDER.

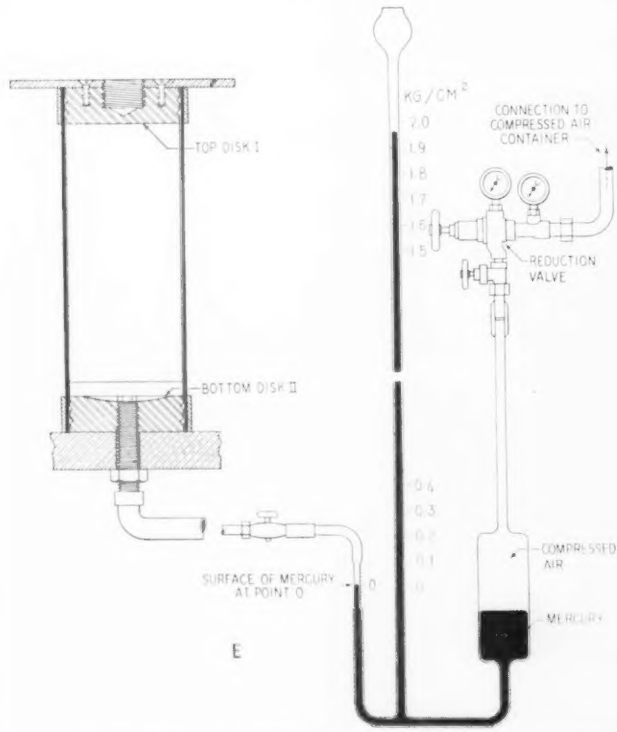

FIGURE 16.—STABILOMETER ASSEMBLY WITH SPECIAL MANOMETER.

pressures to be used during test, laboratory facilities, and personal preferences as to the use of air or liquid in the pressure chamber.

Sample dimensions.—To insure that planes of rupture intersect the sides of samples, their heights should be at least twice their diameters. A diameter of 2 inches is satisfactory for soil which passes the No. 10 sieve.

Samples with larger sized particles require larger diameters. H. N. Hveem has found a diameter of 4 inches satisfactory for certain types of bituminous road surfacings; and the Bureau of Reclamation apparatus is suitable for testing samples up to 6 inches in diameter by 16 inches long.

Chamber walls.—Apparatus of the size illustrated in figures 9, 10, 17, 20, and 21, provides for the testing of samples 2 inches in diameter by 4½ inches high. For tests of such samples the use of transparent tubing for the outer shell of the pressure chamber is recommended, since among other things it provides desirable visual inspection of samples during test.

Use of glass for this purpose, figure 22, was proposed

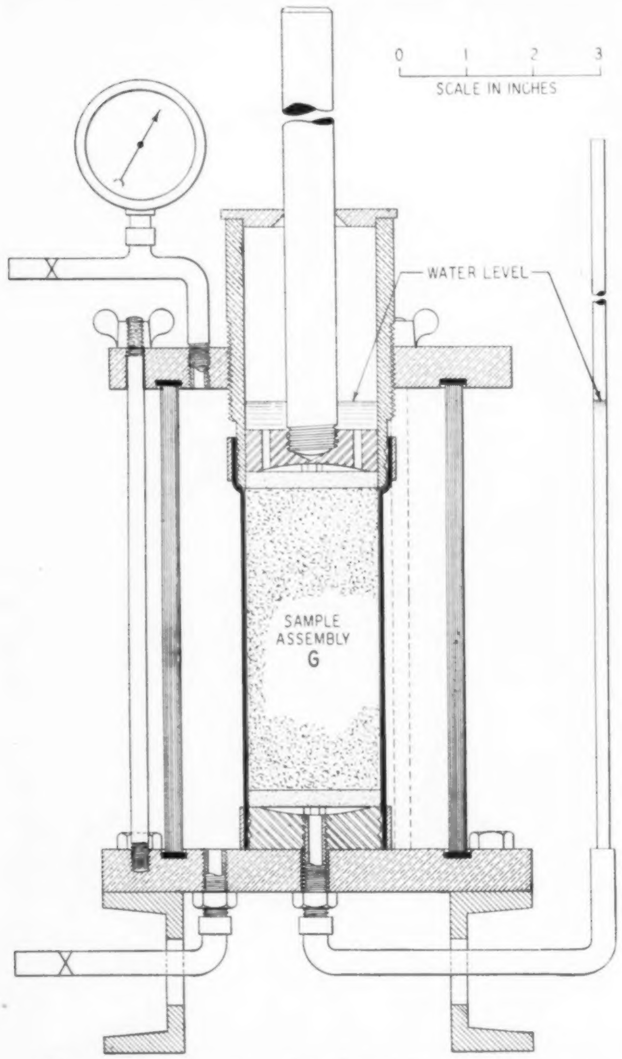

FIGURE 17.—STABILOMETER ASSEMBLY OF THE FIXED RUBBER TYPE.

by Buisman in 1934 and it is still used in European laboratories. The transparent plastics used in this country are recommended as more suitable. Relative to experience with them at Harvard University the Watson report (*20*) states:

> This pressure chamber was designed for and has been successfully used under an internal pressure up to 10 kg. cm.$^{-2}$ Plate BII–1 (fig. 11) shows that it consists of a "Lucite" cylinder enclosed with rubber gaskets between a cast-brass head and base.

For large samples and for the high pressures commonly used to test semirigid pavement surfacing materials, outer cylinders consisting of metal are used. The elaborate apparatus constructed by the Bureau of Reclamation is shown in figure 23. Relative to the latter's apparatus, their report (*22*) states:

> The loading equipment will develop and measure an axial load up to a maximum of 7,500 pounds and deform specimens as much as 4 inches.

Application of load.—Some laboratories use testing machines for applying load to the samples, and measuring their vertical deformations. Others make use of yokes, levers, or threaded plungers to apply the loads, and micrometer dials to measure the deformations.

Figure 24 shows the testing machine used at Harvard

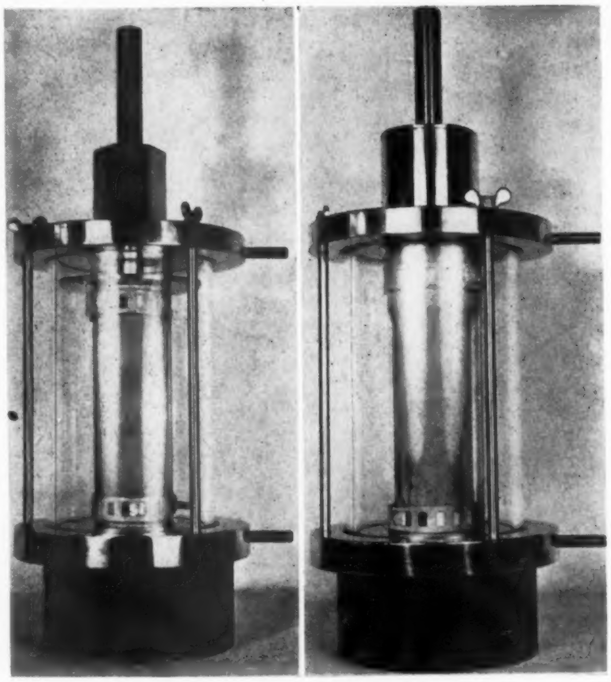

FIGURE 18.—LEFT, FREE, AND RIGHT, FIXED RUBBER TYPES OF STABILOMETER.

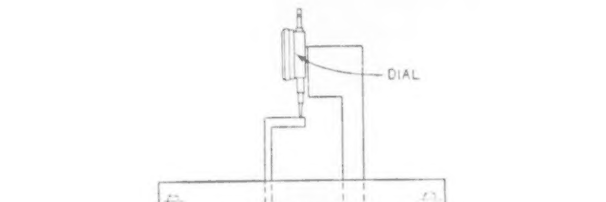

FIGURE 19.—CELL APPARATUS DEVELOPED BY THE DELFT LABORATORIES.

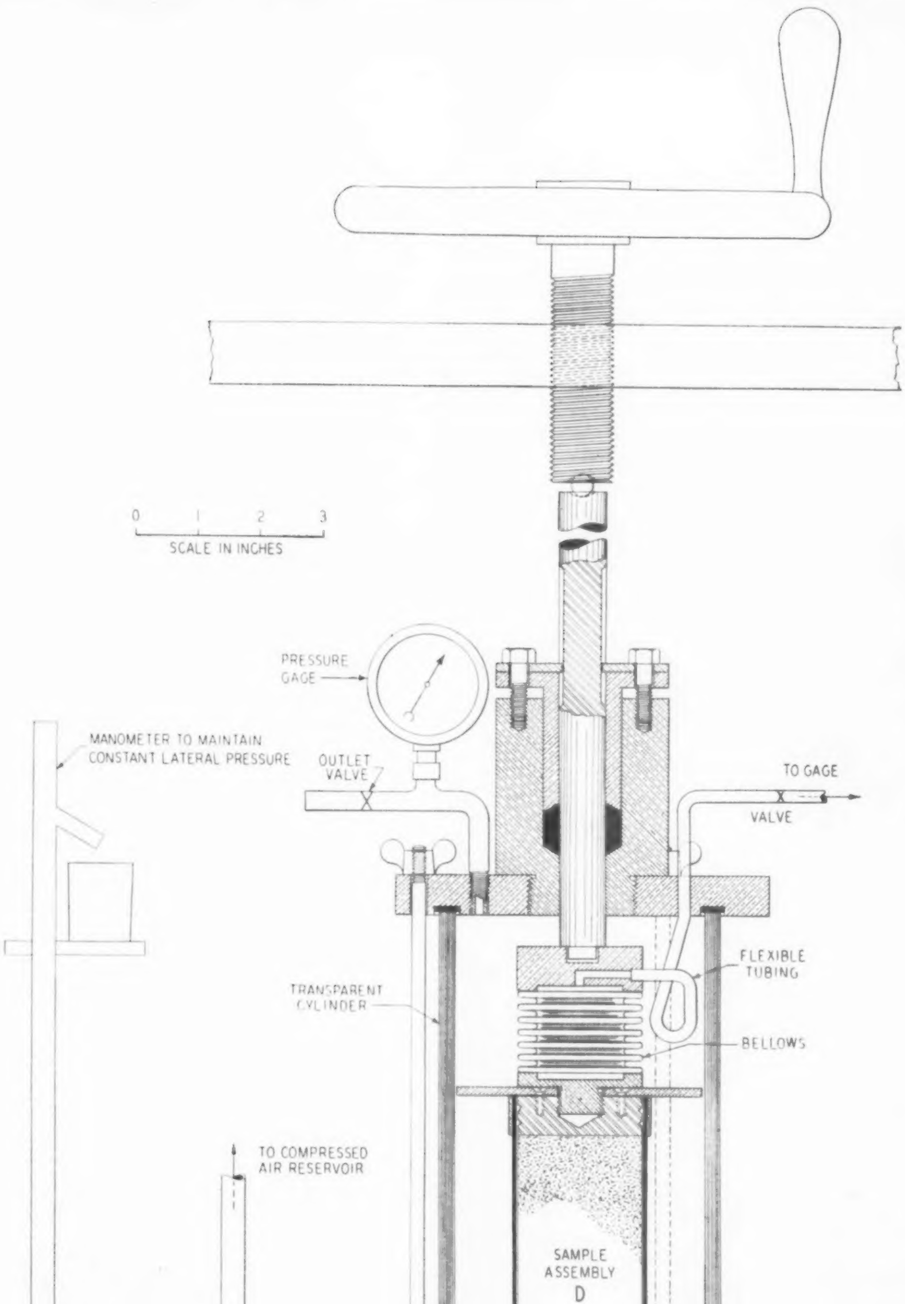

FIGURE 20.—STABILOMETER ASSEMBLY OF THE BELLOWS TYPE.

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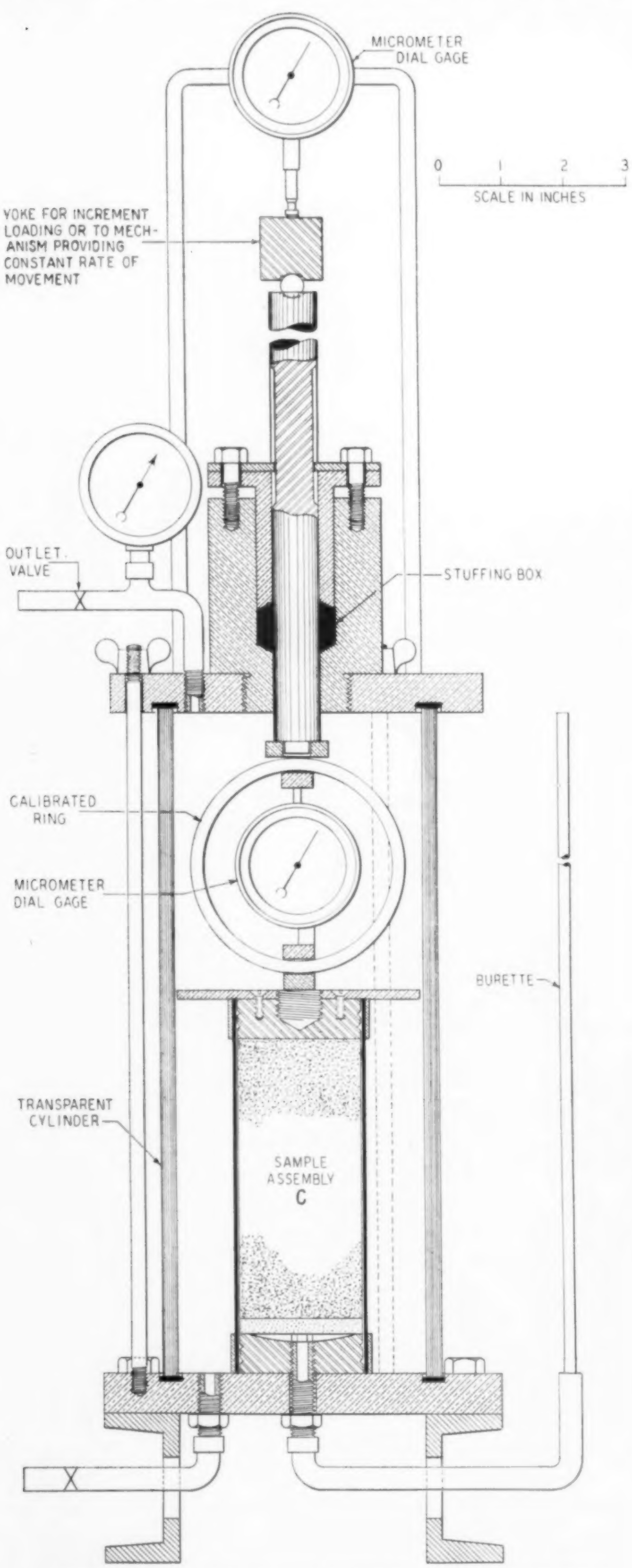

FIGURE 21.—STABILOMETER ASSEMBLY OF THE RING TYPE.

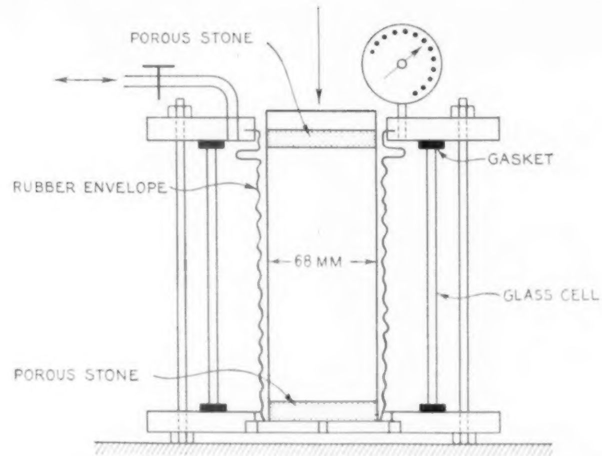

FIGURE 22.—CELL APPARATUS WITH GLASS CYLINDER USED BY BUISMAN.

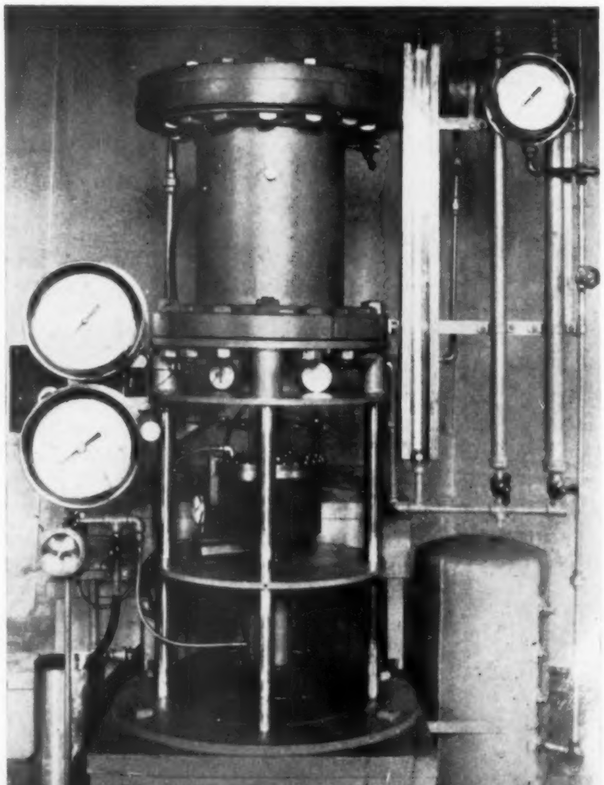

FIGURE 23.—STABILOMETER USED BY THE BUREAU OF RECLAMATION.

University. The method using a threaded plunger is employed by Jürgenson, Hennes, the Bureau of Reclamation, and, in tests of unconfined cylinders, as shown in figure 25, by Burmister.

All methods are considered satisfactory. However, methods causing a constant rate of strain facilitate the determination of deformations indicative of ultimate failure and are therefore preferred.

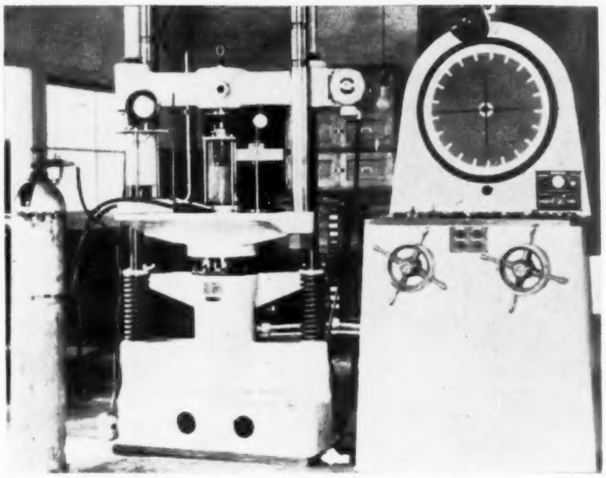

FIGURE 24.—APPARATUS USED IN MAKING TRIAXIAL SHEAR TEST AT HARVARD UNIVERSITY.

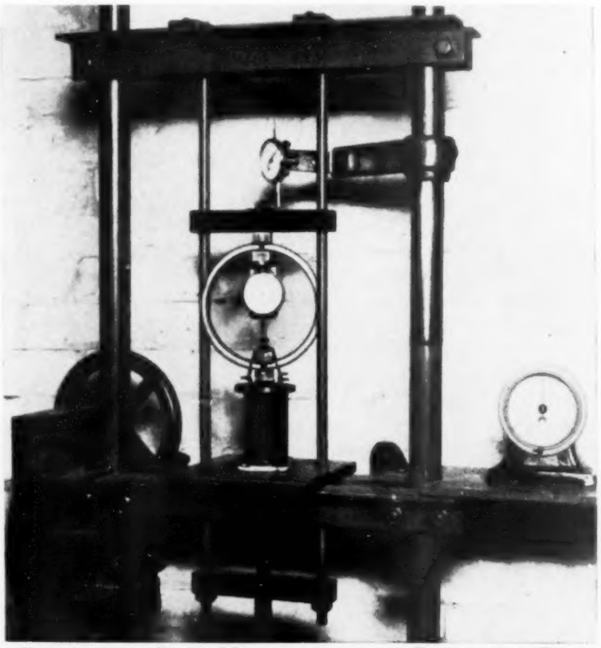

FIGURE 25.—LOAD MEASUREMENT BY CALIBRATED RING.

Pressure chambers.—Except for their tops, the stabilometers, figures 10 and 17, and the consolidation chamber, figure 9, are alike, and all are required for routine stabilometer tests. However, for use in making only occasional tests the one base and cylinder with the three different tops should prove adequate. If the use of glycerine within the chamber or the possibility of leakage from it is considered objectionable, the apparatus, figures 20 and 21, can be substituted for the free rubber type, figure 10.

To make the chambers airtight, packing must be compressed enough to prevent frictionless movement of the plunger. Therefore, means within the chambers to measure vertical pressures applied to the samples is required.

For this purpose use of a sylphon bellows (fig. 20), or a calibrated ring (fig. 21), is suggested. Jürgenson (*15*) placed a bellows inside the chamber, and the Bureau of Reclamation places the bellows on the outside. The calibrated ring has been used in direct shear tests at

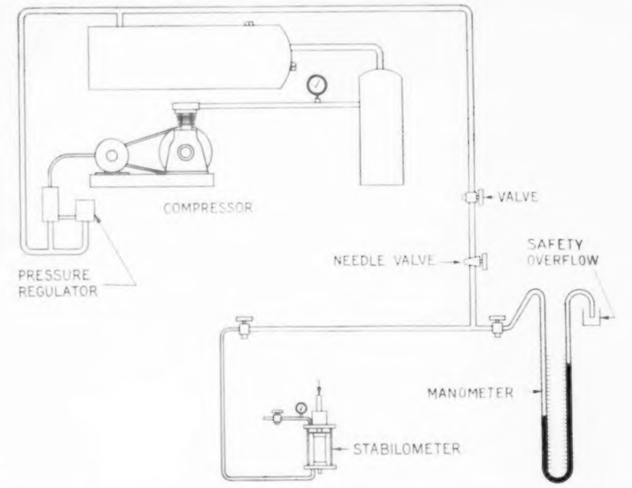

FIGURE 26.—STABILOMETER, MANOMETER, AND COMPRESSED AIR SYSTEM.

Massachusetts Institute of Technology (*29*) and by Burmister (*22*) in unconfined cylinder tests (see fig. 25).

Figure 20 illustrates the use of a manometer for controlling lateral pressures and the threaded plunger method of applying load. Manometers used in Jamieson's early experiments have been employed also in the Delft Laboratories, and to supplement pressure gages in the control of low lateral pressures by the Public Roads Administration. Since provision is made for measuring applied vertical pressures, the threaded plunger is usable to obtain a constant rate of strain. Figure 21 illustrates also an arrangement for measuring vertical movements of the plunger when the loads are applied through yokes.

Chamber pressures.—The air supply system used by the Public Roads Administration, figure 26, provides for pressures up to 125 pounds per square inch and a reservoir of 2-cubic feet capacity. The Bureau of Reclamation's apparatus provides lateral pressures to a maximum of 200 pounds per square inch. Constant pressures are maintained by means of a pressure control device which automatically starts and stops the compressor. For maintaining constant lateral pressures up to at least 10 pounds per square inch, the manometer shown in figure 20 is a valuable supplement to the automatic pressure-control device. For larger lateral pressures, the controlled pressure air reservoir is used.

CLOSED SYSTEM SUGGESTED FOR THE DETERMINATION OF c AND ϕ

Data furnished by direct shear tests illustrate advantages of the closed as compared with the open system of test. Relations of s to n, figure 27, were obtained from data furnished by open system tests, and published elsewhere (*30*). Samples placed between porous stones and consolidated to equilibrium at the moisture contents indicated were sheared at several normal pressures up to and including the consolidation pressure.

To illustrate deficiencies of the data, figure 27, let it be assumed that an embankment which on completion will produce a pressure of 6,000 pounds per square foot, is to be constructed on the soil, at a natural moisture content of 77 percent. At this moisture content and for pressures up to n equals 2,000 pounds per square foot, c equals 1,140 pounds per square foot and ϕ equals 4°. Consolidation by the embankment pressure of 6,000 pounds per square foot can be expected ultimately to

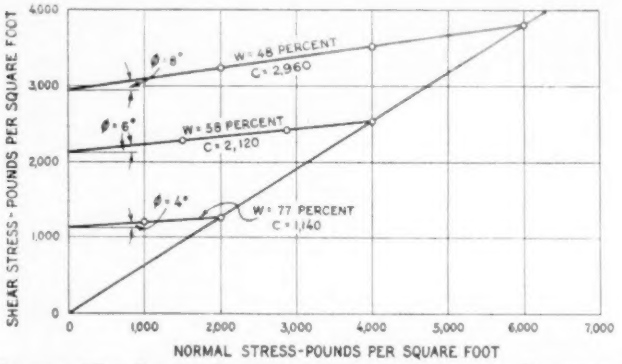

FIGURE 27.—SHEAR STRENGTHS OF SAMPLES AT DIFFERENT MOISTURE CONTENTS, USING THE OPEN SYSTEM.

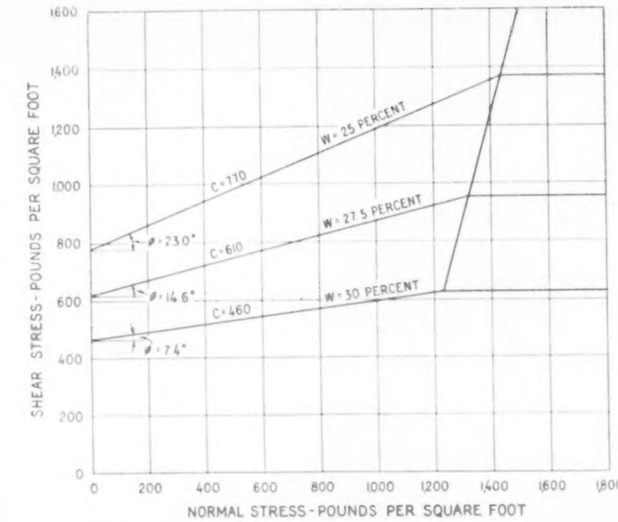

FIGURE 28.—SHEAR STRENGTHS OF SAMPLES AT DIFFERENT MOISTURE CONTENTS, USING THE CLOSED SYSTEM.

reduce the soil's moisture content to 48 percent; and at this moisture content it has for normal pressures up to 6,000 pounds per square foot, values of c equals 2,960 pounds per square foot and ϕ equals 8°.

Depending on the relative speeds of embankment construction and consolidation of the undersoil, excessive pore pressures may be produced which make failure of the undersoil imminent. In such cases it has been considered advisable (*31*) to make use of standpipes inserted in the undersoil so that the speed of its consolidation can be observed.

Information required for the intelligent use of such standpipes necessitates extension of the data, figure 27, to include relations of s to n up to normal pressures of 6,000 pounds per square foot for the samples which contain both 77 and 58 percent moisture.

To obtain the supplementary data, shear tests must be made on samples at normal pressures greater than the consolidation pressures and for this purpose the open system as used in direct shear tests is impractical, because of the rapid speed at which the relatively thin samples used in such tests consolidate.

Therefore, the closed system which furnishes the complete data, figure 28, is deemed more suitable.

To obtain the information given in figure 28, samples compacted at the moisture contents shown were placed between metal plates to simulate the closed system and sheared.

Determination of the pressures at which the relations of s to n change, as shown in figure 28, is especially important since they indicate the upper limit of stresses that can be applied without causing the angle ϕ of the soil at a particular moisture content to become reduced.

Thus, the soil, figure 28, at a moisture content of 30 percent has c equals 460 pounds per square foot and ϕ equals 7.4° for normal pressures up to the limit of n equals 1,230 pounds per square foot. At normal pressures greater than n equals 1,230 pounds per square foot, the shear stress became constant at 620 pounds per square foot.

Change of the soil's character with increase of its ratio of free water to film moisture has long been recognized. As discussed elsewhere (*8*) this ratio may be increased in two ways as follows:

1. By increasing the moisture content of the soil at constant pressure.
2. By increasing the pressure on the soil at constant moisture content.

It has been explained in PUBLIC ROADS (*32*) that increasing the moisture content of semirigid soils at constant pressure increases the ratio of free or lubricating water to the more viscous film moisture, until at moisture contents above the plastic limit the ratio becomes large enough to give soils the properties of plastic instead of semirigid materials. In the same publication, data from tests of unconfined cylinders, which are triaxial shear tests with the lateral pressure l equals 0, showed that at moisture contents above the "critical," which for plastic soils is the plastic limit, the samples exhibited little or no additional strength with increasing deformations above the resistance they had at the plastic limit.

Increasing the pressure (*33*) reduces thicknesses of adsorbed films and therefore, in soil maintained at constant moisture content, causes the ratio of lubricating to film moisture to be increased as effectively as raising the moisture content of soil at constant pressure.

The effect of pressure increase to reduce the lower limit of moisture contents of soil in the plastic state has been reported (*34*).

Therefore, the breaks in the relations of s to n, as shown, are explained on the basis of film phenomena, and for the particular pressures at which they occurred, the respective moisture contents are considered as the critical moisture contents.

What relation, if any, these critical moisture contents bear to pressures required to consolidate the soil has not been disclosed by investigations of the consolidation characteristics of this soil made to determine if any such relation exists.

From the complete data, figure 28, one obtains relations of moisture content to c and ϕ, the stresses at which the soil becomes plastic, and the pore pressure. From such relations and by means beyond the scope of this report, usable safe values of c and ϕ can be selected with respect to the speed of consolidation as indicated by the elevations of water in the standpipes (*35*) inserted in soft undersoils.

SUMMARY

The foregoing presents essential features of what seem to be the most promising methods of making stabilometer tests. It is recognized that compressed air as well as liquid may be used to determine the coefficient, K, and also that the open system may be

(Continued on p. 153)

SAFETY PROMOTION ACTIVITIES OF THE STATE HIGHWAY COMMISSION OF WISCONSIN

By WILLIAM F. STEUBER, Assistant Safety Director, State Highway Commission of Wisconsin

THE SAFETY DEPARTMENT of the State Highway Commission operates on a budget of $50,000 per year. At first thought such a sum may seem ample to eliminate highway accidents altogether. Actually, to conduct a year's safety activity in Wisconsin expenditures must be made very carefully to carry on with $50,000 all the activities that seem desirable.

Wisconsin's population is 2,926,000 persons or 730,000 families. There is only 1.7 cents per person or 6.8 cents per family to spend on safety education. A letter to each family twice a year, urging safe use of the highways, would consume the entire fund in postage and stationery without being an effective approach to the traffic problem.

To use $50,000 effectively in highway safety promotion is a real task. First of all, the expenditures must be pyramidal in effect. That is, a single expenditure must reach one group, then another, and still another, carrying a message to each group. The effect of funds used to support the school safety patrols is a good example. In Wisconsin, belts and badges for school safety patrols are supplied free to schools by the State Highway Commission. Each outfit, one belt and one badge, represents an investment of 37½ cents. Each belt and badge identifies one boy as a safety patrolman. Before he assumes his duties and goes about his patrol tasks he learns the elements of pedestrian safety in traffic. His duty is to protect his classmates in traffic—they are the second group reached.

Teachers in the schools are also reminded of traffic dangers as they guide the safety patrols in their work, thus the teachers make up the third group. The school children tell about the school patrol to smaller children, thereby reaching a fourth group. The school patrol is discussed at home, reaching the fifth group, the parents. Motorists passing the school see the safety patrols at work—a sixth and very large group is reached. Pedestrians who walk past the school and see the patrol boys on duty make up a seventh group.

Thus, for an expenditure of 37½ cents, at least seven different groups of people are reached. But the pyramidal effect does not end here. At the close of the school year the boy turns in his belt and badge and the next school year another boy uses them, a new class is protected, new parents are brought face to face with a safety activity, and a new pyramid is started, all financed by the original expenditure of 37½ cents.

Compilation and use of accident statistics produces a pyramidal effect since they are used by speakers, in newspapers, and over the radio. Creation of county safety councils to conduct local safety programs outlined by the Department carries on the idea of pyramiding. So does the use of motion pictures—films can be projected time after time with low upkeep cost. Driver testing equipment requires little expenditure after the initial cost is paid, and is used by group after group. Each proposed activity of the Safety Department is judged on its pyramidal value, its ability to reach more and more people cheaply and effectively.

The highway safety program in Wisconsin is planned for an attack on the traffic problem at sources of trouble. The State is concerned with the education of the driver, the pedestrian, and the school child. To make the driver and the pedestrian and the school child realize the extent and seriousness of the accident problem, to teach them all that accidents are the result of human failings, to get them to conduct themselves properly in any occasion to avoid accidents, all are functions of the Safety Department of the State Highway Commission.

ACCIDENT STATISTICS USED IN PLANNING SAFETY WORK

Accident records and statistics.—In Wisconsin, traffic accidents that result in a human fatality or injury, or in property damage in excess of $50 must, by law, be reported to the State Highway Commission within 48 hours. The compilation and analysis of the data in these accident reports is a main function of the Safety Department. Statistical studies are made to determine what accident-producing factors deserve the most attention in safety promotional work. Individual reports are strictly confidential, but the statistics of accidents are made public. Much material for newspaper articles, lectures, and radio talks is derived from these statistics. Many special statistical studies are made available to legislative committees, to other State departments, to localities and communities, and to groups and individuals whose special research may require an analysis apart from the regular tabulations. In several instances, detailed studies have been made for persons desiring to use the material in the preparation of theses, and in preparing technical papers or articles for professional publications.

Facts and trends, as shown by these statistical studies, are used by the Safety Department to identify the places where intense safety activity is necessary and to determine the type of safety activity most urgently needed. Statistics are often considered dull by the general public, but they are a necessary foundation in carrying on a comprehensive highway safety program.

County safety councils.—The basic organizations for highway safety promotion in Wisconsin are the county safety councils. Each of the 71 counties of the State has its own safety council that meets regularly and studies the safety needs of the county. The council is organized by and functions under the Safety Department of the State Highway Commission. It consists of a general chairman, a general secretary, and chairmen of committees of engineering, enforcement, education, and publicity. Its members are civic-minded persons who work without pay for the betterment of their community. Each council accepts as its duty a study of community safety needs and suggests to governing bodies solutions of local traffic difficulties. It helps to provide a better understanding between the public, the traffic enforcement officials, and the courts. It counsels the local populace repeatedly in proper behavior of both driver and pedestrian to prevent local traffic accidents.

Through the county safety councils safety programs are arranged in schools, at luncheon clubs, at civic and service meetings, in P. T. A. groups, and in fraternal, industrial, and religious groups. Safety exhibits, meetings, parades, and campaigns are planned and executed by these councils. They maintain speaker bureaus and spot maps; they prepare safety addresses and supply safety news releases to the local papers; and they compile statistics on the traffic accidents occurring in their county. Typical membership in the county council includes county judges, traffic officials, school superintendents and principals, county highway commissioners, representatives of fraternal, service and business clubs, industrial leaders, and professional men as well as those who have no special qualifications other than a wholesome, live interest in the welfare of their community.

Guiding and advising all the county councils is the Safety Department. To the county councils it sends regular letters outlining suggested activities, and field contact men who advise the local officials and learn their ideas to the end that each community benefits by the experience and suggestions of all the others. County councils receive every aid the Safety Department has at its disposal—statistics; supplies of literature for free distribution; special speakers from the Department; motion picture programs on safety with operator, machine, and films furnished; aid in preparing and releasing safety publicity; aid to schools in conducting suggested study courses; and supplies for school safety patrols.

To focus special attention on highway safety in each community of the State, no method better than the county safety councils has been found.

Public contacts.—The personnel of the Safety Department consists of a safety director, an assistant director, a supervisor of publicity, an office manager, a statistician, three district field representatives, a stenographer, three clerks, a publicity assistant, and a part-time student who serves as an additional clerk.

The director, the assistant director, the publicity supervisor, and the three district field representatives maintain close contact with the public in safety promotional work. Each of these six men is a competent public speaker with a background of traffic and safety research and experience. Each of the six meets with the county councils at regular intervals to give advice and to correlate their activities for greatest efficiency. Assistance is given in forming councils and in keeping them active and informed. Assistance by these men is given the county councils when special programs of motion pictures are desired in schools, at clubs, at P. T. A. meetings, or public safety meetings arranged by the councils themselves.

SAFETY PROGRAMS GIVEN TO ANY GROUP REQUESTING THEM

When a council wishes to schedule a program on highway safety with a speaker and motion pictures, arrangements are made to supply them. County superintendents of schools are contacted and through them arrangements are made to present safety programs in the schools. A 45-minute program consisting of a 15-minute safety talk followed by 30 minutes of safety movies is enthusiastically received by students from elementary grades through senior high schools. Of course any of several different speeches and motion pictures can be presented so that the program is in keeping with the particular problems of the audience. A 45-minute program can be given in four schools a day, two in the forenoon and two in the afternoon.

When a Safety Department man comes into a county to conduct these programs, the local council usually keeps him busy. It is not unusual for a safety lecturer to speak at four school meetings a day, plus a luncheon club address at noon and a P. T. A. meeting at night. With such a number of meetings in a single day, it is imperative that the public contact men have a variety of facts at the tips of their tongues, and an ability to blend those facts into an interesting talk. Of prime importance is the ability to sense immediately the interests of the audience and to address it in terms and manner so that the message is vital to the group's own traffic problems.

Public relations is an important phase of the highway safety program in Wisconsin. Any group in any part of the State may address a penny post card to the Safety Department requesting a program, and that program will be provided at no cost to the group. P. T. A. groups, service clubs, luncheon clubs, chambers of commerce, fraternal organizations, 4-H groups, boy and girl scouts, schools, traffic enforcement bureaus, and industrial plants have availed themselves of this service.

In 1938 public relations men of the Safety Department attended 1,183 meetings. Of these meetings, 515 were contacts with Safety Councils, and 668 were highway safety contacts with other groups. A total audience of 162,542 persons was reached with direct messages of highway safety. The county safety councils by themselves held 3,223 safety meetings and reached an additional 229,106 persons.

The Safety Department realizes that regardless of the size of the audiences, all automobile drivers and pedestrians in the State cannot be reached directly. In each address the plea is made for all listeners to carry the appeal for street and highway safety to their families, neighbors, friends, and co-workers. How extensively this is actually done depends in large part upon the quality of the program presented and the competence of the speaker to present his ideas in a manner that generates an urge to carry the message further. With a reduction of 10.5 percent in all traffic accidents in the State and a fatality reduction of 23 percent in 1938 as compared to 1937, it is felt that the accident-prevention work of the county and State organizations has been effective and a worthwhile investment.

Driver testing equipment.—Owing to the importance of agriculture in Wisconsin, county fairs and the State fair are prominent occasions in the State. When plans for fairs are being made, the county safety councils appeal to the Safety Department for aid in promoting highway safety by means of a dignified yet striking display. To comply with these requests, three sets of driver testing equipment have been assembled.

The driver testing equipment has been designed to bring a concrete representation of the problems of automobile driving to an individual without taking him onto the highway. Fundamentally it is similar to the testing equipment used by automobile associations, insurance companies, and others. Briefly, each person who takes the test is subjected to eye examinations, to a glare test, to a distance judgment test, to a coordination test which measures how well the body responds to what the eyes see, and to a test of knowledge of Wisconsin traffic laws. Each of these tests is explained in its relation to actual traffic on the highway.

School Children Are Educated in Traffic Safety by Means of School Patrols, Lectures, Movies, and Instruction in Safe Practices for Bicyclists and Pedestrians.

A score sheet is kept for each individual. At the close of the test the operator in charge analyzes each person's score. If defects are found the individual is told what they are and how to compensate for them in the interests of safety.

Operation of the driver testing equipment is the most elaborate and spectacular safety activity of the Safety Department. In 1938 the driver testing equipment was used in 52 Wisconsin localities and tests were given to 10,428 persons. It is felt that the tests benefit both the persons actually reached and the thousands who also learn a few new traffic facts as they watch their friends go through the lines. Further benefits are derived through newspaper articles based on the results of the tests in each locality. Individual test results are kept confidential, but publicity is given to the scores obtained in each community as well as to facts disclosed by the tests. For example, the tests showed that one man out of every twelve tested was color blind to the extent that traffic lights may be confusing.

The driver testing equipment is valuable in safety promotion because it creates an urge for persons to try it; it is curiosity provoking to onlookers; it creates safety publicity material; and it reveals typical characteristics of drivers.

School contacts.—It is the belief of the Safety Department that every effort to promote safety education in the schools will have a beneficial effect on the traffic picture of the future. Because the achievement of traffic safety requires continued efforts over a long period of time rather than a quick flash of brilliance, the logical place to build for the future is in the schools. The drivers and pedestrians of tomorrow are the school children of today. The Safety Department therefore feels that its most effective work can be accomplished through promoting safety education in the schools of Wisconsin.

School safety patrols have become quite generally accepted throughout the Nation as an effective and necessary safeguard to protect school children from traffic. In Wisconsin, the school safety patrols are directly sponsored by the Safety Department, and the belts and badges for safety patrols are given to the schools by the Highway Commission. The badges bear the name of the Commission. Each school requesting safety patrol supplies gets more than just the belts and badges. Detailed directions for the establishment of the patrol are included as well as descriptions of the exact duties of the patrol members.

In six months of State sponsorship, Wisconsin schools have been supplied with over 4,500 belts and a like number of badges. In many of the counties, belts and badges are first turned over to the county traffic officer. He visits the school, gives a lecture on the duties of school patrols, gives a talk to the student body on cooperation with the patrol for safety, pins the badges on the members, and presents to each member an

official certification card bearing a pledge of office and a list of ten patrol duties. These cards are also supplied by the Highway Commission, and are signed by a representative of the Safety Department and countersigned by the enrolling officer and the school principal. The entire ceremony gives an air of official standing to the school patrol, and goes far toward making each member fully cognizant of his duty and the other school children more respectful of each patrolman's authority.

LITERATURE ON HIGHWAY SAFETY WIDELY DISTRIBUTED

Many excellent safety pamphlets are available for free distribution by the insurance companies, automobile companies, and automobile associations. The Safety Department receives large supplies of this literature. It has prepared a bibliography appraising the value of much of this material, and distributes it in quantity to any school in the State on request. This literature is excellent reference material for teachers and students. Lesson sheets and posters are also distributed throughout the State by the Safety Department.

Members of the Safety Department are frequently asked to address State, district, and county conventions of school boards and teachers. During these contacts, many teachers have asked aid in preparing courses of study in highway safety. Individual or group assistance is always given.

In keeping with modern trends in education, an increasing emphasis has been placed on motion pictures as an aid in teaching highway safety. The Safety Department has a library of 56 reels of 16-millimeter films on street and highway safety. Both sound and silent films are available on a free loan basis to any school equipped with suitable projectors. Schools without projectors have equal opportunity to receive motion-picture programs, for the Safety Department has five portable projectors which handle either sound or silent films. To avail itself of a program, any school without a projector contacts either its county safety council or the Safety Department directly, and one of the public relations men of the Department brings the program to that school and to as many others in the county as he can reach in the time he has available in that area.

The Safety Department in 1938 sponsored a contest for the best courses in safety study arranged by school officials for use within their schools. Awards of silver shields mounted on wall plaques were made for the best course for city schools, the best course for rural schools, and for the best course offered in vocational schools. Awards were made by the safety director of the State Highway Commission at the annual convention of the Wisconsin Education Association.

Courses in safety education in three State normal schools were offered for credit in 1938. These courses were organized by the schools with the assistance of the Safety Department. During 1939 several more normal schools are offering such courses. Providing advance training to those who will teach is of extreme importance to the future of safety education.

From the accident reports coming in to the Safety Department an unusual and effective safety textbook has been compiled. One hundred different typical highway accidents have been selected for inclusion. Names of characters and locations have been changed to fictitious ones, but the circumstances of each accident and the street or highway lay-out have been retained exactly as in the accident report. Each of these 100 accident cases has been repeated on a page of the textbook, complete with a diagram of the accident, an explanation of how it happened, and a summary of the injuries and damages. Concluding each case are questions of this type: Why did the accident happen? Who was to blame? How could this accident have been avoided?

A section of the book preceding the case studies is devoted to a summary of Wisconsin traffic laws. Following the case studies are 150 questions on traffic laws and safety practices. None of the questions is answered in the book, but a set of answers, prepared by a committee of Wisconsin traffic judges, is available to teachers. This textbook is entitled "Traffic Accidents—Their Causes and Their Prevention." It is supplied in quantity to high schools, normal schools, vocational schools, and individuals, free of charge. The popularity of the book is evidenced by the demand for it. In 1938, 30,000 copies were supplied to Wisconsin schools. A 1939 edition of 35,000 copies will be almost entirely used up in filling orders already on hand.

The Safety Department is devoting much of its time, energies, and money to safety education in the school systems. A triple purpose is served when school children are educated in highway safety—greater safety will be assured for the future, immediate results are obtained in greater safety for the youth of today, and much of the material presented to children is repeated at home for the adults and parents to think about.

Enforcement aids.—One of the most necessary aids to a comprehensive highway safety program is the work of the traffic officer. The Safety Department has no direct authority over the county traffic officers or the city traffic departments of the State, yet cooperation and help from these men has been outstanding in quality. Because efficient enforcement tends to reduce the number of accidents, the Safety Department has exerted its influence to effect employment of traffic officers in counties that have previously been without them. In many cases where officers have been employed, the Safety Department has conducted civil-service examinations so that choice of men employed was made entirely upon ability and experience.

The help of the Safety Department has not ended with aid in employing a traffic officer. Present-day enforcement is not confined to arresting violators and investigating accidents. The modern traffic officer is wholeheartedly engaged in safety education as well as in enforcement. In this work of education, the traffic officer visits schools, addresses clubs and safety meetings, frequently prepares articles for the press, and often participates in radio programs. In all of these contacts the services of the Safety Department are at his disposal—accident statistics, posters, literature, school safety patrol belts and badges, motion picture films, and assistance in preparing speeches and news releases.

TRAFFIC SCHOOL OF BENEFIT TO ENFORCEMENT OFFICIALS

Competent traffic enforcement is a highly exacting task calling for excellent qualities of personal efficiency and judgment. Heretofore the officer who had those qualities did his work in a manner meeting with the approval of the motorist and the community; the officer who lacked them was seriously handicapped and means were lacking for adequate training. The traffic officers themselves were the first to realize that regular training schools for traffic officers would help raise the general

A Driver Clinic, Consisting of Various Tests to Determine a Person's Fitness to Drive a Car, Is Popular at Fairs Throughout the State, and Brings the Message of Highway Safety to Thousands. Lower Right, Provision of Safety Lanes for Free Brake Inspection Is One of the Activities of the County Safety Councils.

level of officer efficiency. When the idea of conducting district traffic schools for officers was discussed with them, they endorsed the plan with enthusiasm. So did the county officials under whom the traffic officers work, as well as city officers, chiefs of police, mayors, and traffic justices and judges.

A traffic school has been organized and operates as follows: The State is divided into nine districts corresponding to the nine division areas of the State Highway Commission. Monthly schools are held in each of these divisions. All persons directly interested in traffic enforcement are invited to attend, from village marshals to county judges. One subject is covered at each meeting, in lecture by competent authorities and in supervised discussion by those in attendance. Typical subjects covered in these meetings are: Accident in-

vestigation—obtaining evidence, use of photography and measurements, how to keep records efficiently, first-aid studies; public relations—appearance of officer, approach to a traffic violator, how to get cooperation from witnesses, conduct on and off the job, public speaking hints; court procedure—filing and presenting complaints, the officer's relation to the court, the rules of admissible evidence; and selective enforcement—use of spot maps as reference to accidents, patrolling high-accident areas, checking physical hazards, checking vehicles.

Wisconsin traffic accident statistics show that 51 percent of the accidents are caused by violations of traffic laws. With the traffic officers working to familiarize the citizens with the traffic laws, and with improvement in enforcement methods continuing, even further reductions in traffic accidents and fatalities should result.

Publicity.—Highway safety cannot advance unless the citizenry is aroused to a realization of how acute the problem actually is. Concrete suggestions for improved driving habits and for better pedestrian behavior must get to the general public. The Safety Department receives excellent cooperation from the newspapers, both dailies and weeklies. Practically every Wisconsin newspaper contains at least one good news story each issue on some phase of the traffic problem.

However, the newspapers themselves rarely originate stories on accident prevention. The news value of highway safety information is not apparent to most reporters; or if it is, the reporters often do not have the technical background to offer concrete suggestions of solution.

Of necessity highway traffic news stories with an accident-reduction theme must originate from a source that has accident facts and highway information readily available. Such a news source must be in constant contact with those who are actively engaged in highway safety work. The publicity section of the Safety Department is therefore a vital part of the organization.

Publicity is directed through several channels. The Department publishes "Safety News," a monthly magazine containing items on the activities of the county safety councils, suggested plans of activity for accident reduction, and presenting the latest State and local accident statistics and analyses. This magazine is distributed free within the State to the county safety councils, school authorities, county highway departments, traffic officials, and city authorities. It is also sent outside the State to safety workers in the departments of other States and to Federal departments, including the Library of Congress. Its circulation is now 5,500 copies and is increasing rapidly.

News releases are prepared daily and are mailed to every newspaper within the State. Articles of a general safety nature and special releases dealing with particular local problems are prepared. Use of this material has been almost universal.

The State Highway Commission subscribes to a clipping service. By tabulating the clippings of its stories as they come in, the Commission has an accurate picture of the extent its releases are used by the newspapers. Very often a story sent out as a news release is published in the form of an editorial—infallible evidence that the material submitted was of vital interest to the community.

Newspapers place a high value on printed pictures. The Safety Department releases photographs of unusual accidents or of outstanding safety activities at least once a week. For convenience, these photographs are submitted to the papers as mats so they can be printed at no great expense.

Publicity on traffic safety has other outlets. For distribution at county safety council exhibits and displays at fairs, conventions, expositions, and general meetings, the Safety Department has prepared many types of handout literature. One is "An invitation to drive home safely—we want you with us at our next meeting." Another is a brochure in color reviewing the types of highway signs—what each one means and where they are located. Another is a card illustrating approved hand signals for turning and stopping. Each publication is short and to the point, designed to carry one message since persons visiting a fair or exposition will not spend time reading a lengthy article.

RADIO PROGRAMS ON HIGHWAY SAFETY GIVEN

No modern approach to the public is complete without extensive use of the radio. In Wisconsin the radio stations have cooperated generously in furthering the State Highway Commission's safety activities. Each week end six 1-minute radio scripts on highway safety are prepared and sent to each of the 19 radio stations in the State. The scripts are written as traffic warnings, each one stressing some pertinent danger. A survey of the use of these warnings by the radio stations reveals that they are broadcast at those times of day when radio audiences are at the maximum. The 19 Wisconsin radio stations are so located throughout the State that every community is reached by one or more stations.

Longer radio programs, addresses running up to 15 minutes in length, are prepared at intervals and are submitted to the county councils that have access to radio stations. Local speakers present the addresses over their local stations.

Radio broadcasts are of great value in reaching citizens who do not or cannot attend safety meetings. Since radio stations receive their operating licenses with the stipulation that they offer their services for the public good, no radio station charges for the time devoted to safety promotion work.

That press and radio are effective in carrying safety messages to the motorists is revealed by experience over holiday periods such as Memorial Day, the Fourth of July, and the Labor Day week end. In the year 1937 accidents showed a marked increase over 1936, yet on those three holidays in 1937 there were less than half the fatalities there had been in 1936. The only explanation for the decrease on these days of heavy traffic was that the intense publicity campaign in press and radio and by traffic police had been heeded, resulting in greater motoring care over the holidays. Again in 1938 on those same holidays there was a further reduction over the 1937 record—a percentage of reduction greater than the general reduction for the whole year. Of course the campaign in press and radio and by traffic police was repeated and enlarged for the 1938 holidays.

Motion pictures.—The State Highway Commission of Wisconsin believes strongly in the value of motion pictures as an effective aid in safety education. The elements of traffic—drivers, vehicles, pedestrians, streets, highways—all are ideal material for motion pictures. More concrete suggestions for traffic improvement can be packed into an 11-minute film than can be described in 2 hours by a speaker.

Safety Contests, Spot Maps of Traffic Accidents, and Displays of Accident Statistics Are A Few of the Means Used by the County Safety Councils and the Safety Department in Furthering Street and Highway Safety.

The Safety Department has five portable motion picture sound projectors in constant use and a film library of 56 reels of motion pictures. Each of the three district field supervisors has a projector and the other two are used by the men working out of the main office. In schools or at adult meetings where these men appear, the programs they present begin with a short address on pertinent facts on accidents and suggestions for their prevention. Motion pictures make up the remainder of the program. Films not in use by Department representatives are available for free loan to any group in the State requesting them. Schools, service and fraternal clubs, safety councils, industrial plants, and others have borrowed these films. In 1938 alone the films were shown to a total audience of more than 400,000 persons.

The Department's film library is made up of sound and silent reels on a loan basis from automobile companies, insurance companies, and automobile clubs as well as many films it has purchased outright from the producers. The Department does not distribute films that are obviously advertising in nature, but it does not object to the mention of a commercial concern as sponsor to the picture if the film is primarily one of good safety practices presented in a friendly manner.

MOTION PICTURE FILMS ON HIGHWAY SAFETY PRODUCED BY THE COMMISSION

Supplementing the films available by purchase or loan from outside sources, the State Highway Commission produces motion pictures of its own. No attempt is made to film subjects already covered by available films. The Commission's motion picture productions deal with subjects especially vital to its program of accident prevention. The motion pictures produced by the Safety Department had a 1938 circulation of 412 bookings, reaching a total audience of 71,000 persons. One film, "Wisconsin School Safety Patrols," shows how school children must avoid traffic when no protection is provided. Then in contrast it shows how safety is provided by an efficient school safety patrol. Pictures of the operations of many Wisconsin school patrols are also shown. This film is excellent to take into a community to show what can be done by establishing a patrol.

More than one-third of the persons killed in traffic accidents in Wisconsin are pedestrians. To plead for improved pedestrian habits the Department has produced the motion picture, "We Who Walk." A picture of pedestrians, this film shows how pedestrians walk into trouble. The pictures was filmed in Wisconsin and shows pedestrians jaywalking, roaming behind parked cars, crossing the street in midblock, and loitering in the street. The pedestrians themselves show by their careless actions why they are so frequently hit by automobiles. The film closes by showing correct pedestrian behavior under all conditions in city and country.

"Safety News" is another film produced by the State Highway Commission. It is a news-reel type of production showing the results of traffic accidents throughout the State. Safety activities to prevent traffic accidents by various county safety councils are shown in story form—a parade in one county, a unique driver testing device in another, traffic control in a third, and a brake testing lane in a fourth. The film closes with a plea for comprehensive safety activity in all communities.

"Driving Hazards" shows in pictures the usual and some unusual conditions each Wisconsin motor-vehicle operator must encounter in the course of his driving.

"Watch the Road Signs" is an all-color film showing the history of highway signs and the meaning of sign types now in use. The picture opens showing Indians marking their trails. The horse-and-buggy days follow, showing travelers asking their way. Early crossroad signs are shown; signs which were often inadequate to keep the early motorist from taking the wrong road. Then in contrast the modern highway with its comprehensive sign system is shown. The film continues with pictorial explanations of each type of sign, clearly showing how each type differs in purpose and in appearance from the others. It closes with an appeal to drivers to be guided by the highway signs.

The program of motion picture production by the Safety Department calls for four pictures per year. Contemplated productions for the future are on the subjects of bicycling, traffic enforcement, and a newsreel of unusual safety activities in 1939.

The Safety-Department uses only 16-millimeter films, as that size has become the standard for nontheatrical motion pictures. The Department has its own motion picture camera complete with supplementary lenses, film magazines, and titling and editing equipment. Because of the increasing use of motion pictures in schools, in industry, and at public gatherings, motion pictures on highway safety will in the future have more outlets and reach more people. A recent survey of safety aids to teachers, made by the National Education Association, revealed that "more good films on safety" was recorded as a need by more than 50 percent of the teachers. The Safety Department is attempting to do its share in supplying that need.

Conclusion.—In 1938 there were 23 percent fewer fatal highway accidents in Wisconsin than in 1937. This represents a saving of 203 lives. Injuries in traffic accidents were reduced 8.1 percent while all accidents, including those involving only property damage, were reduced 10.5 percent.

How much do traffic accidents in Wisconsin cost? If a human life is valued at $10,000, if an average injury cost of $500 is taken, and if $150 property damage is assumed for each reportable accident, then the 1937 traffic accident cost was $14,773,500. This amounts to $5.05 for every person in the State. Figured on the basis of cost per motor vehicle (1937 registration was 871,592 vehicles) accidents in 1937 cost $16.95 per vehicle—a cost greater than the average Wisconsin motor-vehicle license fee.

On the same basis of valuation, accidents in 1938 cost Wisconsin $12,220,350. The reduction of traffic accidents and fatalities in 1938, figured on the above scale, saved $2,553,150. The Safety Department operates on a budget of $50,000 per year. Thus for every State dollar spent in highway safety promotional work, a saving of $51.06 in reduced accidents was accomplished in 1938. On the basis of population, the expenditure of 1.7 cents per person in 1938 saved each citizen 87 cents, reducing his annual highway-accident cost from $5.05 to $4.18. The reduction in costs of traffic accidents to each motor vehicle (1938 registration was 857,794 vehicles) was $2.70, bringing the annual traffic-accident cost from $16.95 down to $14.25 per motor vehicle.

The problem of bringing a definite highway safety program to each citizen on a budget of 1 cent and 7 mills per person has been no easy task. To reach almost 3,000,000 persons on a total appropriation of $50,000 calls for a careful appraisal of each activity to see that it reaches the greatest number of persons in the most direct manner to convince them that careful driving is good common sense. The greatest return in safety for the least expenditure has been, and will continue to be, the objective of the Safety Department.

INDEX TO PUBLIC ROADS, VOLUME 19, NOW AVAILABLE

The index to volume 19 of PUBLIC ROADS is now available. In addition to the index a chronological list of articles and a list of authors are given. The index will be sent free to subscribers to PUBLIC ROADS requesting it. Requests should be addressed to the Public Roads Administration, Federal Works Agency, Washington, D. C.

Indexes to volumes 6 to 18, inclusive, are also available and will be sent to PUBLIC ROADS subscribers upon request. Indexes to volumes 1 to 5, inclusive, have never been prepared, and it is not expected that these volumes will ever be indexed.

(Continued from p. 144)

utilized to evaluate c and ϕ. Samples used in stabilometer tests have heights of possibly 10 times the thicknesses of samples tested in direct shear and therefore, according to the theory of consolidation, consolidate only one-hundredth as rapidly and in consequence have considerably less error due to change of moisture content during test in the open system. Such tests made in the Delft Laboratories by what Professor Huizinga terms the quick method (22) are considered satisfactory by him for relatively impermeable soils.

It was the consensus of opinion at the Eighteenth Annual Meeting of the Highway Research Board (36) that:

> The triaxial compression or stabilometer device is the most useful shearing method and despite all obstacles it is proposed to obtain and use complete stress-deformation diagrams in connection with highway problems.

Among the advantages provided by this method of test may be listed the following:

1. Samples have the shape common to usual compaction, permeability, and sampling devices.
2. Properties of samples as a whole instead of only a fraction thereof can be determined.
3. Samples of embankment materials may be tested as compacted and after they have been tested for permeability and capillarity.
4. Samples of road materials may be tested as prepared and after their subjection to saturation, freezing and thawing, and the like.
5. Samples of foundation soils may be tested in their natural undisturbed state and at several other moisture contents to the end that complete relations of moisture content to c, ϕ, and pore pressure are provided.
6. Samples may be tested at pressures similar to those that soils and roads are expected to resist under service conditions.
7. Uniform pressures are applied on the surfaces of samples.
8. All stresses on the sample are measured and may be varied or kept constant as desired.
9. Both the vertical and horizontal deformations can be controlled and are measurable.
10. The data are usable in theories of design.

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HISTORIC HIGHWAYS ILLUSTRATED

Highways of History, a pictorial story of the improvement of transportation in the United States, has recently been published by the Public Roads Administration.

The 35 pictures the publication contains begin with the introduction of horses on this continent by Hernando De Soto in 1539, and trace chronologically the modes of transportation used in the United States up to the present time with special emphasis on highway transportation. Beside each picture is a brief description of the historical significance of the scene. The pictures are photographic reproductions of dioramas created by the Public Roads Administration and now exhibited at the Golden Gate International Exposition at San Francisco.

The pamphlet has been prepared particularly for the use of teachers in elementary schools and for school libraries. A limited free supply is being distributed by the Public Roads Administration, Federal Works Agency, Washington, D. C. Copies are also available by purchase from the Superintendent of Documents, Washington, D. C., at 25 cents each.

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF AUGUST 31, 1939

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 480,680	$ 239,590	19.0	$ 8,581,998	$ 4,266,593	318.5	$ 755,190	$ 375,290	23.1	$ 2,863,176
Arizona				2,123,069	1,430,377	92.0	588,373	368,409	32.9	1,138,637
Arkansas	1,136,548	1,136,037	82.1	2,134,834	2,131,450	138.0	196,261	194,176	4.3	1,741,330
California	3,567,800	1,963,610	39.2	3,058,086	1,657,708	45.4	501,758	265,296	19.8	3,768,993
Colorado	513,050	280,133	9.1	3,800,018	2,122,309	91.0	437,295	246,422	10.1	1,956,104
Connecticut	100,040	50,020	.8	1,978,350	981,636	20.6	159,879	79,939	1.7	1,254,367
Delaware	402,580	200,650	5.7	1,047,253	506,228	28.5	526,644	263,322	4.2	1,018,460
Florida	121,000	60,500	1.4	3,065,361	1,532,681	54.7	1,322,279	660,915	25.3	2,700,462
Georgia	1,596,460	798,230	83.5	6,801,233	3,400,616	358.0	967,651	483,826	67.8	5,589,273
Idaho	561,344	335,701	34.4	2,000,692	1,213,790	87.4	241,539	146,927	13.8	1,210,755
Illinois	1,590,449	787,840	29.2	8,333,951	4,166,328	187.6	3,559,554	1,777,788	69.3	2,745,990
Indiana	1,831,866	915,933	27.8	4,792,414	2,371,607	114.7	2,294,400	1,147,075	44.7	1,859,537
Iowa	586,507	274,500	52.2	5,305,338	2,345,233	177.5	1,283,453	602,175	49.9	940,783
Kansas	401,945	200,972	22.3	3,447,407	1,715,998	150.8	3,524,443	1,761,342	204.6	4,199,353
Kentucky	1,177,522	588,761	25.2	3,414,631	1,705,760	91.2	945,943	472,971	41.9	2,929,704
Louisiana				12,259,936	3,175,601	53.3	1,288,985	607,838	37.3	2,589,430
Maine	717,258	358,628	10.9	2,006,286	1,003,143	52.4	178,230	89,115	4.1	296,539
Maryland	549,500	273,000	9.9	2,696,021	1,334,611	44.6	973,000	481,505	12.2	1,803,410
Massachusetts	1,314,520	657,260	.7	2,034,245	1,014,433	24.4	1,738,647	865,806	12.1	2,480,172
Michigan	919,948	459,010	25.0	4,421,885	2,208,303	129.4	1,911,850	807,850	50.7	2,815,049
Minnesota	939,988	469,994	60.0	6,203,672	3,083,163	335.4	2,873,929	1,431,311	134.8	3,073,784
Mississippi	631,000	231,470	35.1	8,294,088	3,007,345	337.5	1,276,200	619,450	33.0	2,156,780
Missouri	745,320	372,660	28.8	4,881,356	2,428,226	183.5	2,614,591	1,121,128	69.3	4,342,531
Montana	451,429	254,234	26.6	3,300,956	1,868,498	168.6	28,060	15,913		4,502,018
Nebraska	173,101	86,551	24.2	6,209,395	3,104,328	502.4	2,411,628	1,205,814	280.1	2,611,816
Nevada	742,246	642,664	29.0	608,842	523,560	32.2	335	288		1,309,783
New Hampshire	35,028	17,492	3.5	1,089,750	537,371	24.1	528,418	260,319	17.2	911,394
New Jersey	538,290	269,145	6.0	3,552,816	1,774,858	25.4	739,442	369,721	6.5	1,907,061
New Mexico	127,251	78,717	35.0	1,943,029	1,189,651	97.8	246,886	154,081	14.0	1,404,297
New York	1,113,780	556,890	19.6	14,636,010	7,033,557	242.6	2,481,490	1,085,345	43.5	2,059,318
North Carolina	927,960	463,980	52.8	6,414,123	3,201,482	375.2	1,555,830	770,175	62.1	1,630,657
North Dakota	78,830	42,219	14.6	521,709	279,480	46.1	3,053,450	1,636,589	297.5	3,372,730
Ohio	506,200	253,100	4.6	10,341,726	5,102,474	114.8	2,349,840	1,109,920	21.4	6,529,162
Oklahoma	197,269	103,154	4.9	3,203,482	1,700,365	75.4	1,875,669	997,704	99.5	3,520,579
Oregon	380,270	231,860	21.5	2,589,728	1,567,887	106.5	873,095	514,790	44.6	1,764,978
Pennsylvania	1,078,604	539,302	15.4	10,408,627	5,018,661	99.5	2,514,555	1,253,601	32.7	4,224,357
Rhode Island	129,150	64,575	2.6	689,376	344,381	7.6	380,506	189,885	4.3	1,043,358
South Carolina	537,210	241,000	20.7	2,324,824	1,036,486	65.6	232,000	98,000	24.7	2,397,197
South Dakota	830,555	459,214	102.1	4,014,859	2,243,310	374.6	1,235,190	696,300	92.6	3,357,105
Tennessee	223,860	111,930	4.0	4,155,644	2,077,822	117.1	414,640	207,320	9.0	4,392,963
Texas	3,836,494	1,886,900	249.6	10,206,312	5,051,553	462.2	1,403,864	683,185	47.1	6,511,955
Utah	882,760	632,080	36.7	1,613,260	1,168,085	80.0	210,510	147,590	13.5	822,644
Vermont	459,811	225,631	11.1	280,548	140,034	7.0	147,400	73,700	4.8	630,064
Virginia	966,130	482,520	28.6	2,925,287	1,420,890	75.0	835,657	412,114	24.5	1,000,657
Washington	1,125,541	587,959	6.8	2,428,432	1,266,640	32.3	840,626	323,758	9.2	1,079,838
West Virginia	534,427	303,875	19.4	2,400,755	1,217,614	53.6	1,170,603	584,957	38.0	1,846,232
Wisconsin	1,690,625	834,523	74.6	7,685,324	3,784,610	233.9	987,154	446,255	35.3	1,631,793
Wyoming	364,641	225,241	34.2	1,197,223	747,754	104.3	703,200	435,219	87.3	780,297
District of Columbia				130,624	65,312	.8	264,800	132,400	1.7	289,788
Hawaii	133,706	64,635	1.0	994,580	475,460	16.3	574,217	282,968	9.8	1,056,640
Puerto Rico	302,230	150,315	6.4	1,555,549	772,020	31.2	96,128	47,440	1.2	405,020
TOTALS	38,252,723	20,464,205	1,457.8	210,104,914	103,517,282	6,688.5	58,315,287	29,005,227	2,289.0	118.468.320

STATUS OF FEDERAL-AID SECONDARY OR FEEDER ROAD PROJECTS

AS OF AUGUST 31, 1939

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 186,105	$ 91,750	13.7	$ 873,345	$ 349,000	19.4	$ 90,100	$ 45,050	9.7	$ 739,456
Arizona	56,191	40,524	11.0	225,057	161,795	22.4	21,128	15,238		322,699
Arkansas	286,997	284,639	35.3	251,392	250,221	35.8	161,841	161,790	19.2	321,892
California	110,917	63,199	17.1	1,031,194	529,642	31.2				762,115
Colorado	140,928	78,065	7.8	661,208	346,829	20.8	95,856	46,892	4.8	114,772
Connecticut				172,794	72,417	2.9				286,249
Delaware	80,840	40,420	17.5	73,930	36,965	7.8				231,250
Florida	106,317	52,800	3.4	883,305	437,294	34.2				374,950
Georgia	160,720	80,360	20.1	326,120	163,060	39.1	133,260	66,630	19.2	1,073,008
Idaho	101,455	60,357	1.5	368,562	174,486	40.3				202,031
Illinois	457,113	228,216	17.0	1,337,200	614,600	89.0	255,100	127,550	20.6	690,385
Indiana	232,000	116,000	18.5	895,170	446,381	71.4	130,926	65,463	9.7	660,414
Iowa	11,587	5,328	11.8	94,399	44,241	15.4	480,447	225,635	86.5	1,404,603
Kansas				47,588	23,794	11.7	583,633	296,596	41.7	1,259,390
Kentucky	117,736	41,185	9.7	1,061,032	286,860	66.4	856,726	296,918	72.0	223,613
Louisiana	202,622	98,805	19.6	515,473	232,522	38.2	363,402	160,120	30.3	341,124
Maine	211,924	105,962	11.8	249,556	123,692	15.2	48,500	24,250	2.3	6,575
Maryland	57,600	28,800	7.8	143,670	71,835	8.2	205,000	72,055	12.6	362,991
Massachusetts				344,984	171,164	7.6	372,470	184,000	7.5	434,504
Michigan	223,900	111,950	7.1	1,197,904	582,752	97.3	337,500	168,750	17.3	873,402
Minnesota	184,910	92,318	10.6	704,453	350,319	66.3	238,593	119,296	32.2	1,096,571
Mississippi	176,500	88,250	6.8	500,662	224,646	36.3	406,800	213,300	41.4	624,670
Missouri	166,164	82,230	25.8	761,040	372,906	92.3	629,715	260,918	71.0	551,104
Montana	111,913	63,475	10.8	702,330	398,292	58.3	61,495	32,683	5.9	837,578
Nebraska	301,935	141,625	63.9	846,530	416,708	138.8	158,745	79,372	31.3	378,528
Nevada	109,499	94,925	15.0	117,798	101,366	26.5	26,563	23,035	1.6	122,530
New Hampshire				62,951	30,804	2.4	43,023	20,639	.9	168,522
New Jersey				429,020	211,770	15.0	136,820	68,410	9.4	511,778
New Mexico	27,411	17,107	1.8	422,613	254,401	26.3	44,885	28,013	12.7	225,025
New York	366,400	183,200	18.9	1,965,760	971,930	99.6	833,600	285,572	11.3	488,791
North Carolina	281,780	140,890	20.0	1,094,224	547,090	104.9	60,550	29,760	7.4	329,105
North Dakota	115,030	61,606	8.3				107,790	57,757	10.7	841,099
Ohio	94,160	47,080	6.1	757,570	384,250	39.3	296,000	148,000	9.7	1,716,022
Oklahoma	73,190	38,943	.8	219,796	107,065	9.8	513,715	273,338	28.5	908,099
Oregon	200,005	120,440	28.4	532,452	301,842	47.2	79,829	15,820	12.6	291,255
Pennsylvania	1,168,909	572,778	70.9	1,248,548	618,169	54.7	598,162	294,781	23.9	370,483
Rhode Island	41,487	20,720	.7	57,848	28,924	1.4	72,008	36,004	.2	98,167
South Carolina	219,307	87,390	21.3	364,600	151,679	35.6	330,400	142,044	22.2	204,807
South Dakota				12,340	6,790		5,070	2,790	4.1	1,048,470
Tennessee	343,180	147,890	18.0	390,836	179,948	14.0				858,499
Texas	1,034,825	481,034	132.1	1,387,460	677,595	110.3	190,339	94,165	36.1	1,071,473
Utah	108,785	60,906	14.7	112,815	61,957	20.8	17,800	12,000	4.0	197,199
Vermont	91,158	45,153	4.0	102,682	51,341	3.1	123,680	23,642	4.7	56,385
Virginia	335,770	160,389	34.0	326,214	161,471	31.5	285,600	133,335	19.4	220,142
Washington	386,938	202,678	19.8	383,574	201,118	29.1	103,829	53,400	11.2	210,806
West Virginia	108,950	54,475	6.2	49,215	24,607	2.1				513,414
Wisconsin	195,748	97,693	18.4	866,455	432,527	15.9	279,545	138,268	8.5	580,770
Wyoming	406,669	251,210	22.3				343,427	211,171	33.6	55,604
District of Columbia				14,592	6,796	.1	38,500	19,250	.5	47,079
Hawaii	91,030	45,515	3.7	214,970	107,485	4.6				167,000
Puerto Rico				178,504	86,825	10.4	101,148	49,445	4.6	60,233
TOTALS	9,486,605	4,928,280	814.0	25,581,735	12,590,171	1,771.9	10,263,520	4,823,145	813.0	25,536,631

PUBLICATIONS of the PUBLIC ROADS ADMINISTRATION
(Formerly the *BUREAU OF PUBLIC ROADS*)

Any of the following publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. As his office is not connected with the Agency and as the Agency does not sell publications, please send no remittance to the Federal Works Agency.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1931. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1933. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1934. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1935. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1936. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1937. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1938. 10 cents.

HOUSE DOCUMENT NO. 462

Part 1 . . . Nonuniformity of State Motor-Vehicle Traffic Laws. 15 cents.

Part 2 . . . Skilled Investigation at the Scene of the Accident Needed to Develop Causes. 10 cents.

Part 3 . . . Inadequacy of State Motor-Vehicle Accident Reporting. 10 cents.

Part 4 . . . Official Inspection of Vehicles. 10 cents.

Part 5 . . . Case Histories of Fatal Highway Accidents. 10 cents.

Part 6 . . . The Accident-Prone Driver. 10 cents.

MISCELLANEOUS PUBLICATIONS

No. 76MP . . The Results of Physical Tests of Road-Building Rock. 25 cents.

No. 191MP . . Roadside Improvement. 10 cents.

No. 272MP . . Construction of Private Driveways. 10 cents.

No. 279MP . . Bibliography on Highway Lighting. 5 cents.

Highway Accidents. 10 cents.

The Taxation of Motor Vehicles in 1932. 35 cents.

Guides to Traffic Safety. 10 cents.

An Economic and Statistical Analysis of Highway-Construction Expenditures. 15 cents.

Highway Bond Calculations. 10 cents.

Transition Curves for Highways. 60 cents.

Highways of History. 25 cents.

DEPARTMENT BULLETINS

No. 1279D . . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922. 15 cents.

No. 1486D . . Highway Bridge Location. 15 cents.

TECHNICAL BULLETINS

No. 55T . . . Highway Bridge Surveys. 20 cents.

No. 265T. . . Electrical Equipment on Movable Bridges. 35 cents.

Single copies of the following publications may be obtained from the Public Roads Administration upon request. They cannot be purchased from the Superintendent of Documents.

MISCELLANEOUS PUBLICATIONS

No. 296MP. . Bibliography on Highway Safety.

House Document No. 272 . . . Toll Roads and Free Roads.

Indexes to PUBLIC ROADS, volumes 6–19, inclusive.

SEPARATE REPRINT FROM THE YEARBOOK

No. 1036Y . . Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Ohio (1927).

Report of a Survey of Transportation on the State Highways of Vermont (1927).

Report of a Survey of Transportation on the State Highways of New Hampshire (1927).

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio (1928).

Report of a Survey of Transportation on the State Highways of Pennsylvania (1928).

Report of a Survey of Traffic on the Federal-Aid Highway Systems of Eleven Western States (1930).

UNIFORM VEHICLE CODE

Act I.—Uniform Motor Vehicle Administration, Registration, Certificate of Title, and Antitheft Act.

Act II.—Uniform Motor Vehicle Operators' and Chauffeurs' License Act.

Act III.—Uniform Motor Vehicle Civil Liability Act.

Act IV.—Uniform Motor Vehicle Safety Responsibility Act.

Act V.—Uniform Act Regulating Traffic on Highways.

Model Traffic Ordinances.

A complete list of the publications of the Public Roads Administration (formerly the *Bureau of Public Roads*), classified according to subject and including the more important articles in PUBLIC ROADS, may be obtained upon request addressed to Public Roads Administration, Willard Bldg., Washington, D. C.

STATUS OF FEDERAL-AID GRADE CROSSING PROJECTS

AS OF AUGUST 31, 1939

STATE	COMPLETED DURING CURRENT FISCAL YEAR					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	NUMBER: Grade Crossings Eliminated by Separation or Relocation	NUMBER: Grade Crossing Structures Reconstructed	NUMBER: Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	NUMBER: Grade Crossings Eliminated by Separation or Relocation	NUMBER: Grade Crossing Structures Reconstructed	NUMBER: Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	NUMBER: Grade Crossings Eliminated by Separation or Relocation	NUMBER: Grade Crossing Structures Reconstructed	NUMBER: Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 474,150	$ 473,200	3	1		$ 784,912	$ 783,384	13			$ 28,108	$ 27,900		1	1	$ 815,773
Arizona						469,516	443,841	5			69,362	69,362	1			211,730
Arkansas	104,053	104,053	2			85,838	85,838	1			719,056	710,203	5		8	581,453
California	288,422	288,422	3			1,494,155	1,493,060	8								1,303,375
Colorado	294,383	294,383	3		4	313,042	292,252	2		5	52,046	48,284			16	817,198
Connecticut						172,722	161,008		1							850,557
Delaware						9,150	9,150	2			2,320	2,320			1	513,891
Florida						503,994	503,994	3			130,037	129,201	1		1	1,032,656
Georgia	27,440	27,440	1			399,840	399,840	6			144,673	144,673	2	2	10	2,294,067
Idaho						314,492	282,961	4								466,886
Illinois	1,473,775	1,472,915	7	2	13	1,889,760	1,766,372	13	1	37	381,405	363,755	1	1	23	2,083,108
Indiana	208,408	208,408	2		8	787,675	787,675	2	1	61	480,309	479,309	1	2	21	827,038
Iowa	264,726	249,000	5			196,228	165,906	7		2	533,515	499,500	3		123	1,188,268
Kansas	245,805	245,805	3			695,011	695,011	8		3	466,826	466,826	5		5	1,075,447
Kentucky	100,576	100,576	1	1		675,746	627,797	10	3		671,980	671,980	6			522,281
Louisiana						594,134	594,116	5			670,863	617,362	14			584,469
Maine	259,690	259,690	2	2		291,655	291,655	3	1							220,802
Maryland						291,197	194,405	2		2	46,200	46,200			13	986,891
Massachusetts	104,330	104,220		1		418,236	417,082	4	1		14,320	14,320	1			1,711,447
Michigan	162,900	162,900	1	1		710,976	710,976	6	1		547,920	547,920	2		39	1,603,746
Minnesota	41,045	41,045	1	1		1,359,812	1,342,381	7	5	11	48,099	48,099	1		2	1,489,278
Mississippi						606,714	606,714	8			37,300	37,300	1			894,187
Missouri	65,589	64,284	1			1,197,536	1,197,536	7	1		474,961	435,060	1	4		1,613,080
Montana	439,450	439,450	4			458,244	458,244	6			147,055	50,805	2			276,452
Nebraska	28,481	28,481	1			1,124,384	1,124,384	24	1		149,269	149,269			41	637,289
Nevada	119,640	119,640		1		50,017	50,017		1		36,218	36,218			13	105,520
New Hampshire	11,649	11,649	3		1	150,935	150,431	5			42,980	42,980	1			316,424
New Jersey						629,721	629,721	2	2	1	119,560	119,560		1		1,426,875
New Mexico						75,081	75,081	2			2,572	2,572			1	682,071
New York	440,550	439,450		3		2,029,732	1,975,462	8	8		1,068,844	901,543	5	3		3,679,243
North Carolina	315,050	315,050	3	1	13	1,065,270	1,030,170	6	4	6	231,650	231,650	4		27	955,265
North Dakota	60,590	60,590	1	1		858,712	810,310	11			75,960	75,960	1			395,838
Ohio	63,730	63,730	2			1,545,013	1,508,251	13	1		438,780	389,590	2	1	2	3,101,450
Oklahoma	193,200	159,200	2		7	104,880	104,880			35	307,750	295,850	4	1	8	2,112,947
Oregon	21,689	21,689				148,072	146,777	1			135,740	135,740	2			311,060
Pennsylvania						2,161,799	1,949,900	5	3		620,652	412,200	2	1	2	4,301,128
Rhode Island	103,716	103,716		2		335,075	335,075	1	1							152,459
South Carolina	15,630	14,428		1		633,716	579,200	8	2		225,479	225,479	2	2	35	854,114
South Dakota	8,190	8,190			2	307,520	307,520	3	2	9	83,750	83,750	1	1	6	1,052,620
Tennessee	2,700	2,700			1	654,506	654,506	2	2		239,060	239,060	1	2	4	1,314,533
Texas	196,135	195,800	2	1		2,703,230	2,672,102	23	2		707,549	630,930	5		26	1,894,533
Utah	51,810	51,810	2		6	61,408	61,408	1		23	297,280	297,280			110	186,570
Vermont	18,878	14,256			2	17,642	17,452			5						318,248
Virginia	80,557	80,557	1		11	620,110	527,210	8	2	5	135,880	135,880		1	4	923,109
Washington	33,602	33,602			4	293,142	291,732	3	1	2	66,494	66,494		1	6	505,318
West Virginia	N 40,817	40,817				334,034	318,274	7			20,600	20,600	1		2	959,142
Wisconsin	195,093	194,417	2		1	1,315,849	1,271,665	13	1	1	154,014	154,006		1	9	1,147,209
Wyoming	27,424	27,424	1		3	111,589	111,589		1	4						516,862
District of Columbia						292,412	258,868	1								119,318
Hawaii	50,320	50,320	1			132,850	132,850	3	1							359,450
Puerto Rico						394,352	392,150	9								426,676
TOTALS	6,634,193	6,573,307	60	19	76	32,871,636	31,798,183	291	50	212	10,826,436	10,056,990	78	25	559	52,719,351